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MINERAL LAND CLASSIFICATION OF STANISLAUS COUNTY, CALIFORNIA

1993

CALIFORNIA DEPARTMENT OF CONSERVATION

Division of
Mines and Geology

SPECIAL REPORT 173

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MINERAL LAND CLASSIFICATION

OF

STANISLAUS COUNTY, CALIFORNIA

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1993

SPECIAL REPORT 173

CALIFORNIA DEPARTMENT OF CONSERVATION
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PREFACE

The Surface Mining and Reclamation Act of 1975 (SMARA) was enacted to promote the conservation of the State's mineral resources and to ensure adequate reclamation of mined lands. Among other provisions, SMARA requires the State Geologist to classify land in California for mineral resource potential. Presently, mineral land classification studies are being conducted in several counties of the state.

Upon completion of each study, the State Geologist submits the mineral land classification report to the State Mining and Geology Board, which transmits the information to appropriate local governments that maintain jurisdictional authority in mining, reclamation, and related land-use activities. Upon receipt of the information, local governments are then required to establish mineral resource management policies to be incorporated into their general plans, which must recognize the information submitted by the State Geologist.

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EXECUTIVE SUMMARY

The California Surface Mining and Reclamation Act of 1975 requires the State Geologist to classify land into Mineral Resource Zones (MRZ) according to the known or inferred mineral potential of that land. This process is based solely on geology, without regard to existing land use and land ownership. The primary goal of mineral land classification is to ensure that the mineral potential of land is recognized by local government decision-makers and considered prior to making land-use decisions that would preclude mining.

The study area covers approximately 1,500 square miles and includes all of Stanislaus County and a small portion of San Joaquin County along the Stanislaus River, which forms the boundary between the two counties. For simplicity, the study area is called "Stanislaus County."

This report provides information on all known and potential mineral resources in Stanislaus County, which are grouped under three main categories: construction aggregate, industrial minerals, and metallic minerals. This information is presented on 18 Plates that accompany the report.

In this report the term "concrete-grade aggregate" includes both portland cement concrete-grade aggregate and asphaltic concrete-grade aggregate.

Important findings of this study are:

- At the present rate of production and consumption, the currently permitted concrete-grade aggregate **reserves** in Stanislaus County--totaling 27.7 million tons--will be depleted by the year 2002.

- Estimated **total concrete-grade aggregate resources** for all Aggregate Resource Areas are approximately 540 million tons.

- Stanislaus County currently consumes more concrete-grade aggregate than it produces. In 1991, Stanislaus County consumed about 95 percent (2.45 million tons) of the concrete-grade aggregate produced within the county. In addition, an estimated 650,000 tons of concrete-grade aggregate consumed within Stanislaus County in 1991 were imported from outside of the county. This aggregate was imported from areas in San Joaquin County and Tuolumne County.

- To meet the anticipated demand for concrete-grade aggregate caused by population growth over the next 50 years, it is estimated that the annual production of concrete-grade aggregate in Stanislaus County will have to increase from 2.6 million tons in 1991 to nearly 5.3 million tons by 2043.

- As of January 1, 1993 there were 21 active aggregate mines within the study area; 19 are within Stanislaus County, two are in San Joaquin County. Twenty produce concrete-grade aggregate, while one mine in Stanislaus County produces a small amount of road base aggregate used on local gravel roads. At present and for the near future, the most important area of Stanislaus County for mining is the upstream portion of the Tuolumne River from Waterford to La Grange--an area with eleven producing aggregate mines and substantial concrete-grade aggregate resources.

- Several alluvial fans along the west side of the San Joaquin Valley are potential sources of concrete-grade aggregate for future land development in this region. These deposits are of lesser overall quality, however, than those along the Tuolumne and Stanislaus Rivers.

- Twenty-two areas within Stanislaus County have been classified as **MRZ-2a** ("mineral resource zones" that contain **known** significant mineral deposits) or **MRZ-2b** ("mineral resource zones" that contain **inferred** significant mineral deposits). Together, these areas total about 32 square miles and represent about 2 percent of the study area. Of this total area, 13 areas constituting 92 percent (29.4 square miles) are underlain by concrete-grade construction aggregate resources. The remaining nine areas (2.6 square miles) are underlain by industrial minerals, including kaolinitic clay, diatomite, quartz (silica), and specialty sand.

- Within the 13 areas classified as MRZ-2a and MRZ-2b for concrete-grade construction aggregate, 55 **Aggregate Resource Areas** (ARA) covering 22.03 square miles are identified. An ARA is an area deemed available for mining based on criteria set by the State Mining and Geology Board.

- Seventeen Aggregate Resource Areas, covering 14.48 square miles, have been identified as **Immediately Significant** because they contain active aggregate mines. Three Aggregate Resource Areas, which cover 3.03 square miles, are identified as **Highly Significant** because each contains at least 18 million tons of concrete-grade aggregate resources. Thirteen Aggregate Resource Areas, which cover about 3.36 square miles, are identified as **Significant** because each contains at least 1.8 million tons of concrete-grade aggregate resources.

- Mineral commodities mined in the past in Stanislaus County include construction aggregate (sand and gravel), industrial minerals (diatomite, clay, mineral pigment, magnesite, quartz, and dimension stone), and metallic minerals (chromite, placer gold, manganese, mercury, platinum, and silver). The only mineral commodity mined today in Stanislaus County is sand and gravel. This commodity will continue to be the most important one mined in the near future. Among other commodities, those with the highest future economic potential are kaolinitic clay, diatomite, crushed stone, and specialty sand.

- Six small areas in eastern Stanislaus County have been classified as MRZ-2a or MRZ-2b for deposits of kaolinitic (ball) clay or specialty sand. This region is likely to have other significant deposits of these commodities, which could be revealed by additional exploration.

- Three areas in western Stanislaus County have been classified as MRZ-2b for deposits of diatomite, specialty sand, or quartz (silica). Although low-grade, the deposits of diatomite are large and amenable to open-pit mining.

- For all other industrial minerals classified--dimension stone, magnesite, expansible shale, and bentonitic clay--no area has been classified higher than MRZ-3a (deposits are present, but their significance is not known).

- For all metallic minerals classified--mercury, lode gold, silver, copper, lead, zinc, chromite, and manganese--no area in Stanislaus County was classified higher than MRZ-3a.

- Within the Coast Ranges portion of Stanislaus County, there is potential (MRZ-3a or MRZ-3b) for important deposits of mercury, lode gold, manganese, and chromite. The latter two commodities are expected to be of economic interest only during national emergencies, however. The presence of lode gold was apparently not documented in this part of the county prior to this study.

- Within the Sierra Nevada foothills portion of Stanislaus County, there is potential (MRZ-3a or MRZ-3b) for important deposits of base metals (copper, zinc, and lead), and precious metals (lode gold and silver).

- Concentrations of placer gold in Stanislaus County are probably too low to justify commercial mining of that commodity alone. Extraction of placer gold as a by-product of aggregate mining is often economic and expected to continue, however.

PART I

DESCRIPTION AND SETTING OF PROJECT

PART I - DESCRIPTION AND SETTING OF PROJECT

INTRODUCTION

In 1988, Stanislaus County was selected for study of its mineral resources under the California Surface Mining and Reclamation Act of 1975. Faced with a stagnant economy at present and a projected high population growth in the future, the county must plan for the protection and wise use of its mineral resources to support both this expected increase in population and the recovery of its economy.

BACKGROUND

More than ever, government agencies must make difficult decisions on how to best manage land in ways that avoid both incompatible uses and uses that might result in the loss of mineral resources. Because the availability of mineral resources is vital to our society's way of life, it is essential that the mineral resource potential of land be considered in the land-use planning process. Thus, the main purpose of this report is to provide information on mineral resources that can help local government agencies in Stanislaus County make informed decisions on land use before land with important mineral deposits is committed to uses incompatible with mining.

The California Surface Mining and Reclamation Act of 1975 (SMARA) requires the State Geologist to classify land according to the presence or absence of significant mineral deposits. These reports on "mineral land classification" are prepared under guidelines adopted by the California State Mining and Geology Board (1983). As they are completed, the State Mining and Geology Board transmits the classification reports to appropriate local lead agencies, such as the Stanislaus County Department of Planning and Community Development. These agencies are then required to establish policies on mineral resource management to be incorporated into their general plans, which must recognize the information submitted by the State Geologist.

SCOPE OF PROJECT

The area studied during this project includes all of Stanislaus County and a small portion of San Joaquin County, where the Stanislaus River forms the boundary between the two counties. The area within San Joaquin County was studied for construction aggregate resources only, whereas all of Stanislaus County proper was studied for all mineral commodities. For simplicity, we refer in this report to the entire study area as "Stanislaus County" or "the county."

Earlier studies of Stanislaus County by the Division of Mines and Geology (Charles, 1947; Boalich, 1921; Laizure, 1925; Lowell, 1915; Watts, 1890, 1892) emphasized reports on individual mines and prospects in the county and presented little information on the relationship of the geology of the county to its mineral resources. In contrast, the present study uses the geologic information to classify the overall mineral resource potential of the entire county for all mineral commodities. Emphasis is placed on the identification of local and regional geologic features and characteristics that control or influence the formation of mineral deposits.

PROCEDURE OF STUDY

The study was conducted intermittently between 1988 and 1993 by various staff of the Division of Mines and Geology. Chris Higgins and Don Dupras wrote the main text and assembled the accompanying classification maps; they are responsible for the content and interpretations. Dupras evaluated the resource potential for construction aggregate, and Higgins evaluated the resource potential for all other mineral commodities in the county. Rodger Chapman, with assistance from Les Youngs and Gordon Chase, collected and interpreted geophysical data. Ron Churchill performed geochemical analyses and assisted in their interpretation. Laurel Jensen, Cynthia Pridmore, and John Clinkenbeard compiled geologic and mine data in the early stages of the project.

The first phase of the project involved research of pertinent records and literature on the geology, geophysics, geochemistry, and mining history of the county. Interviews were held with county planners, other geologists, and mine operators familiar with the county.

The second phase of the project consisted of extensive field work to directly evaluate the geology, known mineral deposits, and mineral resource potential of the county. Substantial time was required to contact property owners and to arrange access to their land for this phase. Specifically, areas of important rock units and structures were visited as were many mines and prospects. Details on known mines and prospects are presented in Appendix A. Rock samples were collected for study in the laboratory. Geochemical analyses of the rock samples were done both in a commercial laboratory and in the laboratory of the Division of Mines and Geology in Sacramento; details on the procedures and results are presented in Appendix B. Geophysical data collected in the field included gravity, ground magnetic, and seismic refraction; details on the data and results of these surveys are presented in Appendix C. Many photographs were taken during the study, a few of which are presented in Appendix D.

The final phase of the project was integration and analysis of all the above data to prepare mineral land classification maps of the county according to guidelines adopted by the California State Mining and Geology Board (1983). These maps show Mineral Resource Zones (MRZ) and are presented as several accompanying plates at a scale of 1:48,000. Locations of known mines and prospects are shown on Plates 8A, 8B, and 8C.

GEOGRAPHIC SETTING

Stanislaus County, which covers about 1,500 square miles, is situated in Central California astride the Central (Great) Valley (Figure 1). Locally, this part of the Central Valley is known as the San Joaquin Valley. The county also incorporates parts of the Coast Ranges in the southwest and the Sierra Nevada in the northeast. It is covered by all or parts of 43 U.S. Geological Survey 7.5-minute quadrangles as shown in Figure 2.

The central part of the county is relatively flat. The northeast is composed of rolling hills, which represent a dissected upland. The southwest is composed of rugged mountains. Maximum elevations are along the southwestern border, which is the main crest of the Diablo Range; the highest point is Mt. Stakes at 3,804 feet. Minimum elevations are along the San Joaquin River; the lowest point is about 15 feet above sea level, where the river flows northward into San Joaquin County. The three main rivers are San Joaquin, Stanislaus, and Tuolumne, all of which have their headwaters in the Sierra Nevada.

Stanislaus County is largely rural, with a reported population in 1991 of 388,200 (data from California Department of Finance, Demographic Research Unit, 1992). The largest city, which is also the county seat, is Modesto, in the center of the county (Figure 1). All other important cities are in the Central Valley, which is the main area of the county's most important economic base, agriculture. The main components of this base are row crops and orchards, dairies, poultry, and cattle ranching. The transportation network is well-developed, with several major highways and railroads that traverse the county.

LAND USE IN THE COUNTY

Approximately 95 percent of Stanislaus County is privately owned. The largest tract of public land is Henry W. Coe State Park, in the southwesternmost part of the county.

Most land in the county is currently used for agriculture. The county's general plan (Stanislaus County Department of Planning and Community Development, 1988) states that, as the primary industry, agriculture will be "promoted and protected."

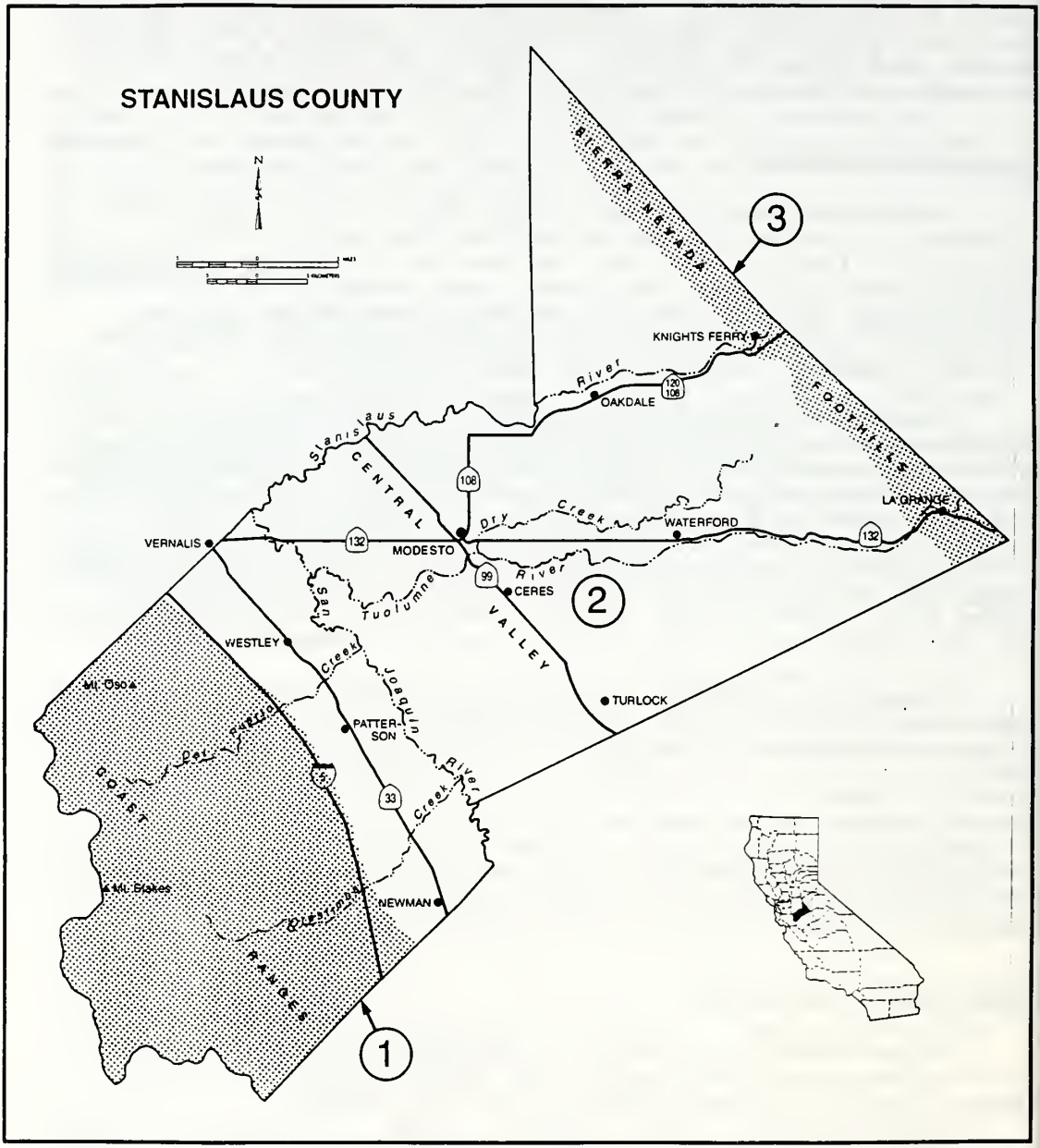


FIGURE 1. – Location and geographic features of Stanislaus County. The geologic provinces of the county are approximately outlined as follows: (1) Coast Ranges, (2) Great Valley, (3) Sierra Nevada.

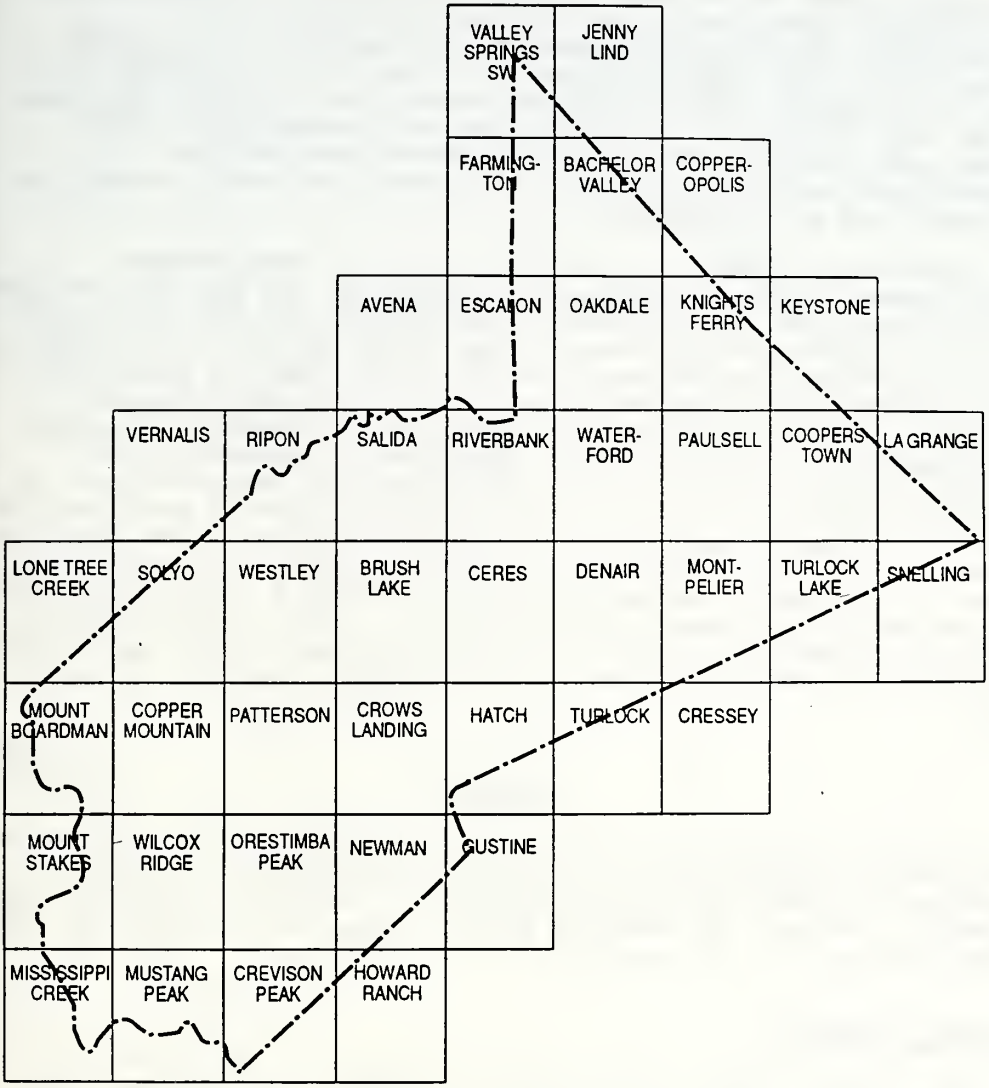


FIGURE 2. – Index of U.S. Geological Survey 7.5' quadrangle maps covering Stanislaus County.

The second main use of land is for residential and commercial development. Most growth has occurred by expansion of incorporated areas into adjacent agricultural areas; a large percentage of the explosive growth in the 1970s and 1980s was from an influx of people from the nearby San Francisco Bay Area to the west (Figure 1). Recently, as an alternative to this pattern of urban growth, several "planned residential communities" have been proposed in Stanislaus County, mostly in the west half of the county.

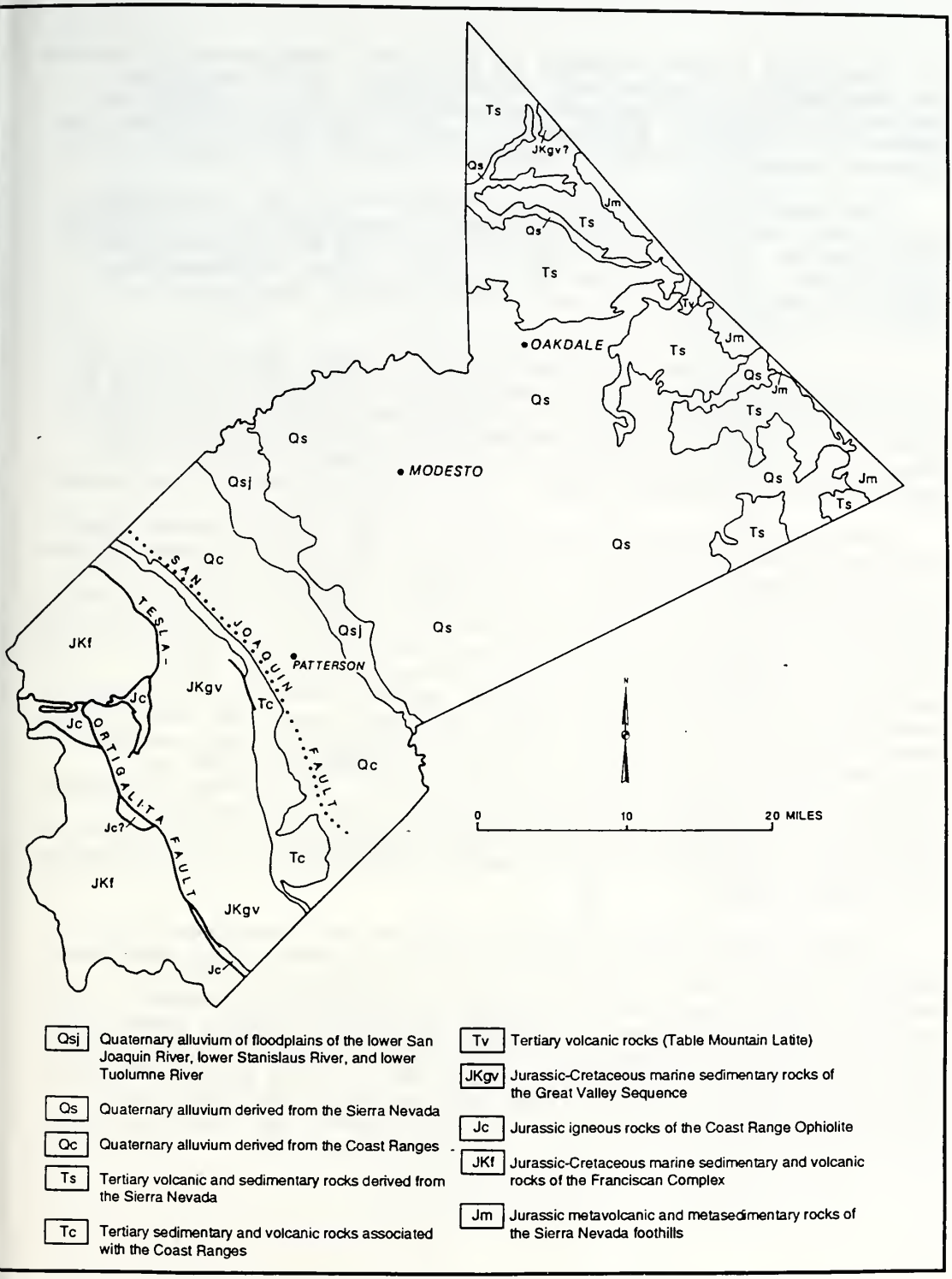
Population growth, agriculture, and, to some degree, establishment of parks and natural preserves are the uses of land that compete most directly with conservation and use of mineral resources in Stanislaus County. The county has had a high rate of growth over the last 20 years, which is expected to continue; urbanization could encroach on areas with important mineral resources, and at the same time, require such resources as the raw materials for construction. The mineral commodity most affected by this situation is sand and gravel. Without far-sighted planning and recognition of these potential conflicts in land use, areas of important mineral resources could be lost for future use or be of insufficient size to supply the county's needs. Fortunately, the county has acknowledged this situation in its general plan by stating (Policy 27, p. 123): "The County shall discourage conversion of lands with significant deposits of extractive natural resources (e.g. sand and gravel) to urban uses."

GEOLOGY

In this section, we present the geologic characteristics and development of Stanislaus County, the complexity of which has resulted in a wide diversity of mineral resources. Reference can be made to the set of detailed geologic maps that accompany this report (Plates 1A, 1B, and 1C).

REGIONAL OVERVIEW

Stanislaus County is situated in parts of three geologic provinces. From west to east, these are the Coast Ranges, Great Valley, and Sierra Nevada. The boundary between the Coast Ranges and the Great Valley provinces is interpreted here as the abrupt change in topography from relatively flat plain to hills. The boundary between the Great Valley and Sierra Nevada provinces is more transitional and is interpreted here to approximately coincide with the area where the contacts between older Cenozoic and Jurassic rocks are exposed. The general locations of the provinces are shown in Figure 1. A generalized geologic map of the county is shown in Figure 3.



Qsj	Quaternary alluvium of floodplains of the lower San Joaquin River, lower Stanislaus River, and lower Tuolumne River	Tv	Tertiary volcanic rocks (Table Mountain Latite)
Qs	Quaternary alluvium derived from the Sierra Nevada	JKgv	Jurassic-Cretaceous marine sedimentary rocks of the Great Valley Sequence
Qc	Quaternary alluvium derived from the Coast Ranges	Jc	Jurassic igneous rocks of the Coast Range Ophiolite
Ts	Tertiary volcanic and sedimentary rocks derived from the Sierra Nevada	JKf	Jurassic-Cretaceous marine sedimentary and volcanic rocks of the Franciscan Complex
Tc	Tertiary sedimentary and volcanic rocks associated with the Coast Ranges	Jm	Jurassic metavolcanic and metasedimentary rocks of the Sierra Nevada foothills

IGURE 3. – Generalized geology of Stanislaus County. Geology modified from Wagner and others (1981) and agner and others (1990).

The Coast Ranges Province is the most lithologically diverse and structurally complex part of the county. It is composed dominantly of marine sedimentary rocks with lesser amounts of igneous and nonmarine sedimentary rocks. This province hosts the greatest variety of mineral deposits found in the county.

The Great Valley Province is characterized by relatively flat-lying Cenozoic alluvial sediments formed by the coalescence of successive alluvial fans derived from the Sierra Nevada and Coast Ranges. It is host to all current mining in Stanislaus County as well as the rich soils that support the county's extensive agriculture.

The Sierra Nevada Province forms a narrow, hilly strip in the northeasternmost part of the county. It is characterized by an irregular pattern of older Cenozoic sedimentary and volcanic rocks that overlie Jurassic metavolcanic and metasedimentary rocks. It has been the ultimate source of most of the metallic and nonmetallic minerals mined in the eastern part of the county.

The regional geologic structure of the county ranges from relatively simple in the east to very complex in the west (Figure 4). The central and eastern parts of the county comprise a relatively stable structural environment, characterized by the successive deposition of Cretaceous and Cenozoic sediments over a gently inclined, eroded crystalline basement. The western part of the county represents an area of intense tectonism, which continues today, as demonstrated by earthquakes and the youthful geomorphology of the Coast Ranges Province. Here, the rocks have been extensively folded and faulted, initially during eastward-directed subduction and then during development of the San Andreas Fault System in western California. At present, this part of the county is apparently undergoing northeast-southwest compression and resultant shortening, oriented at right angles to the boundary between the Coast Ranges and Great Valley (Wentworth and Zoback, 1989).

Regarding mineral resources, the geologic development of Stanislaus County over the last 60 million years or so has been the most significant time period for development of those resources that have the most economic potential at present or in the near future. Figures 5a through 5i (Bartow, 1991) show, in a generalized way, the geologic environments present in and around Stanislaus County at different times during this period. In the next two sections, details about the various rock units and structures associated with these environments, as well as those prior to 60 million years ago, are presented.

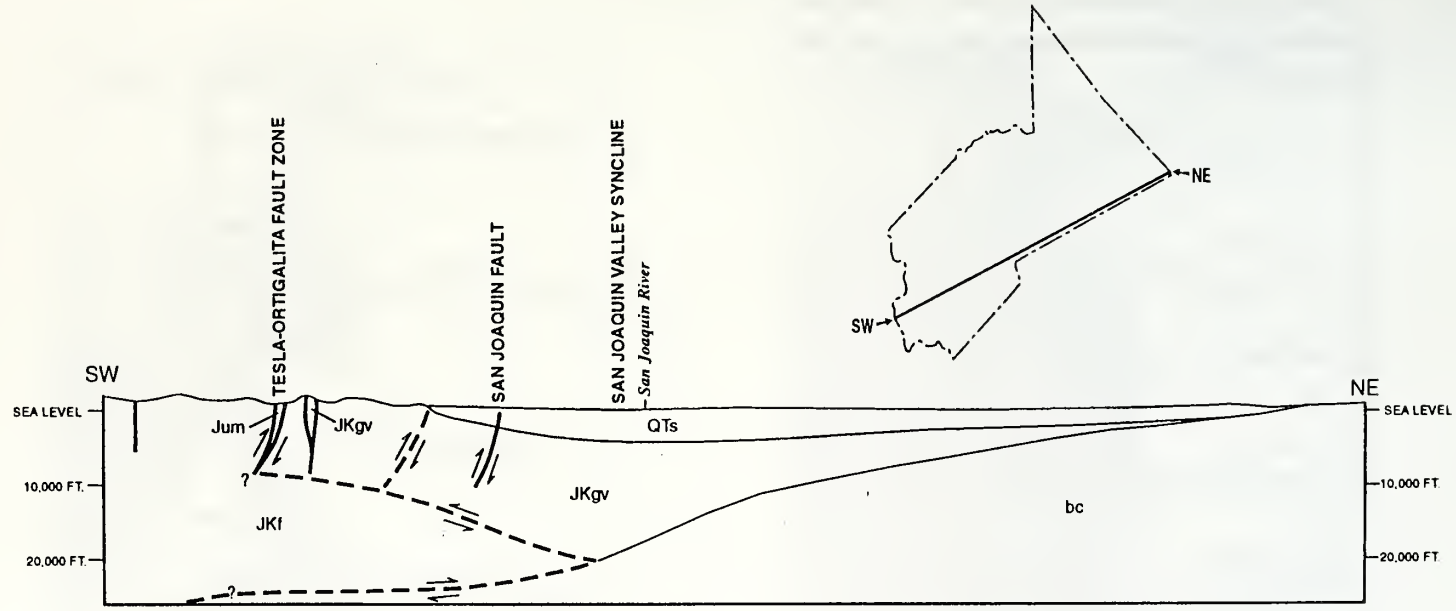


FIGURE 4. – Generalized geologic cross section across southern Stanislaus County. Rock units are as follows: QTs–Quaternary and Tertiary sedimentary rocks and minor volcanic rocks, JKgv–Great Valley Sequence, JKf–Franciscan Complex, Jum–Jurassic ultramafic rocks, bc–Pre-Cenozoic crystalline basement complex. Thick lines are faults; arrows show sense of movement. Vertical exaggeration 2X. Modified from Bartow (1991).

FIGURES 5a through 5i – Geologic development of Stanislaus County and surrounding region during the Cenozoic. Adapted from Bartow (1991).

EXPLANATION FOR FIGURES 5a - 5i

Marine deposits—Solid line indicates inferred shoreline; hachures indicate inferred shelf edge; queried where uncertain

Nonmarine deposition—Dotted line indicates inferred extent; queried where uncertain

Lacustrine deposition

Emergent area—Queried where uncertain

Volcanic center

Faults—Queried where uncertain. Arrows indicate direction of relative movement

Probably active

Possibly active

Future trace of Neogene San Andreas fault

Thrust—Sawteeth on upper plate

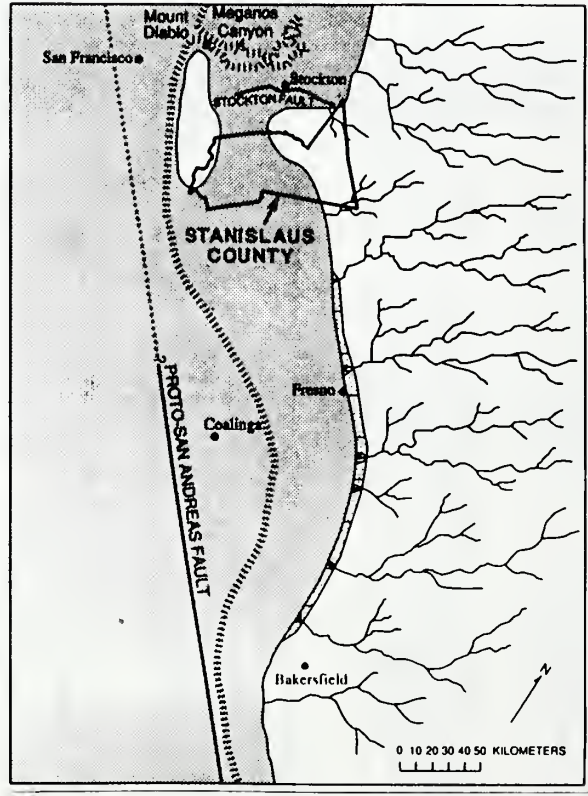


FIGURE 5a. – Late Paleocene (about 59 million years ago).

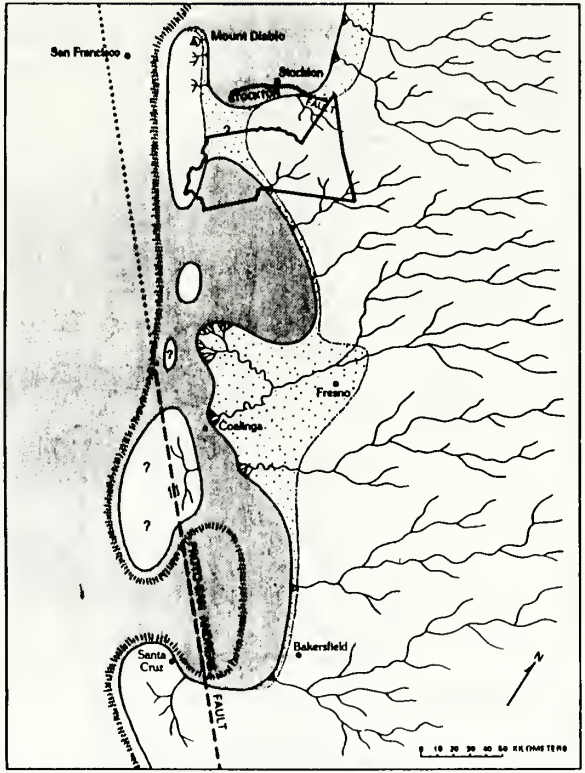


FIGURE 5b. – Early to middle Eocene (about 52 million years ago). See Figure 5a for explanation.

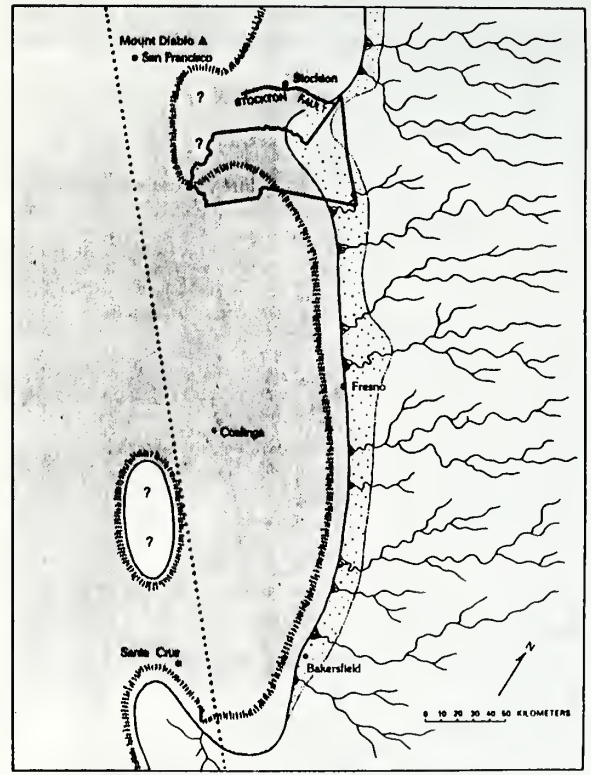


FIGURE 5c. – Middle Eocene (about 44-45 million years ago). See Figure 5a for explanation.

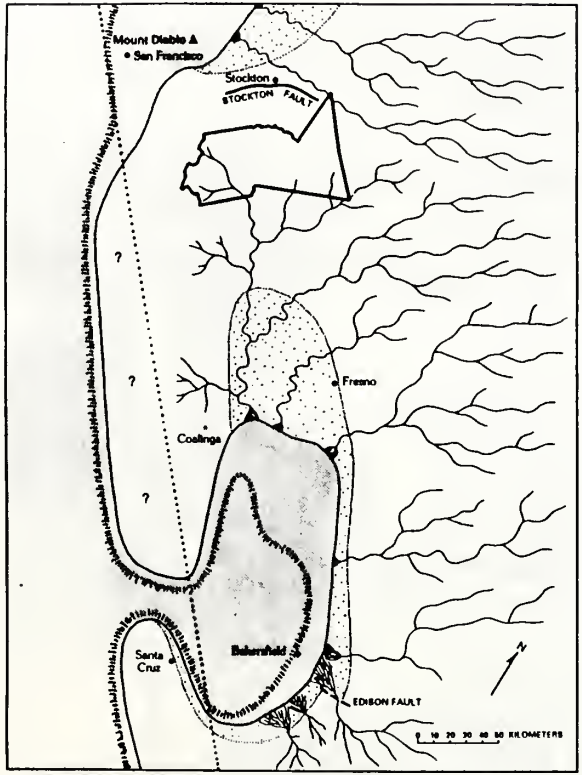


FIGURE 5d. – Oligocene (about 30 million years ago). See Figure 5a for explanation.

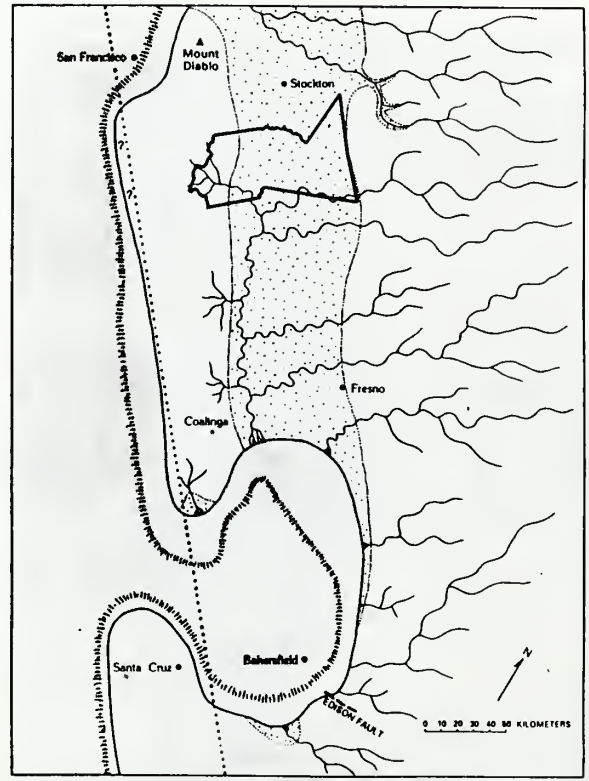


FIGURE 5e. – Early Miocene (about 20-21 million years ago). See Figure 5a for explanation.

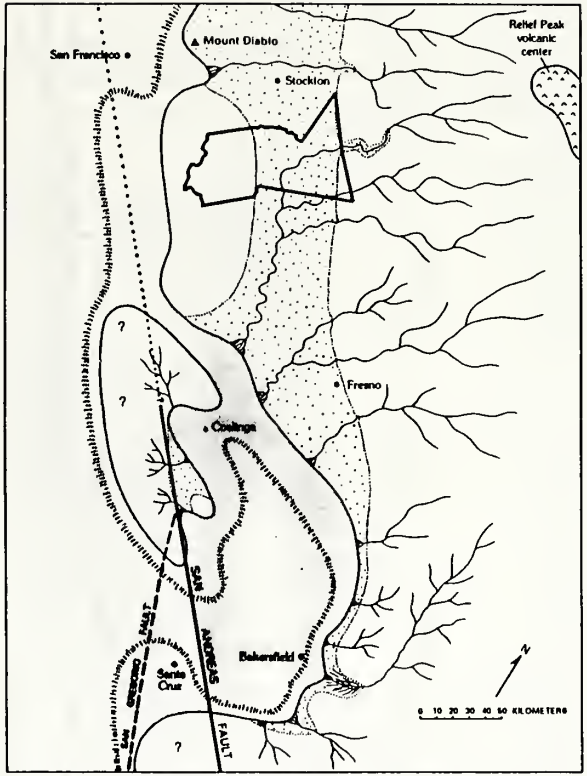


FIGURE 5f. – Middle Miocene (about 16 million years ago). See Figure 5a for explanation.

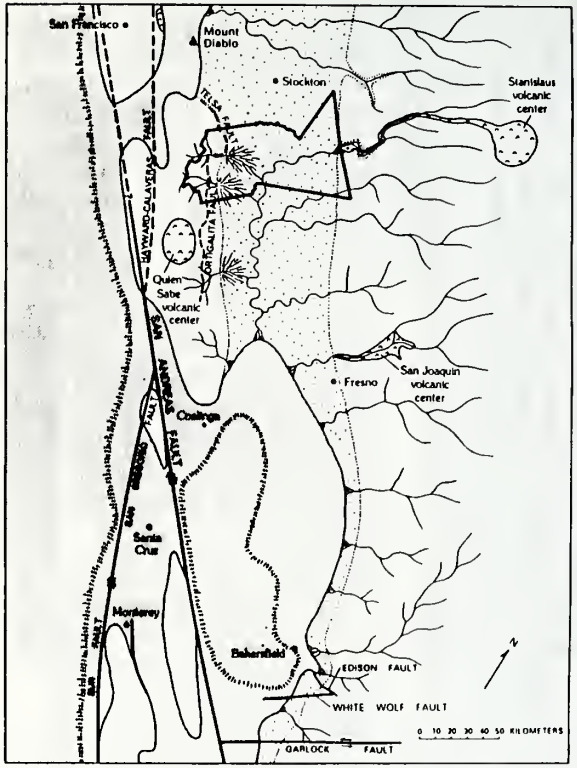


FIGURE 5g. – Late Miocene (about 9-10 million years ago). See Figure 5a for explanation.

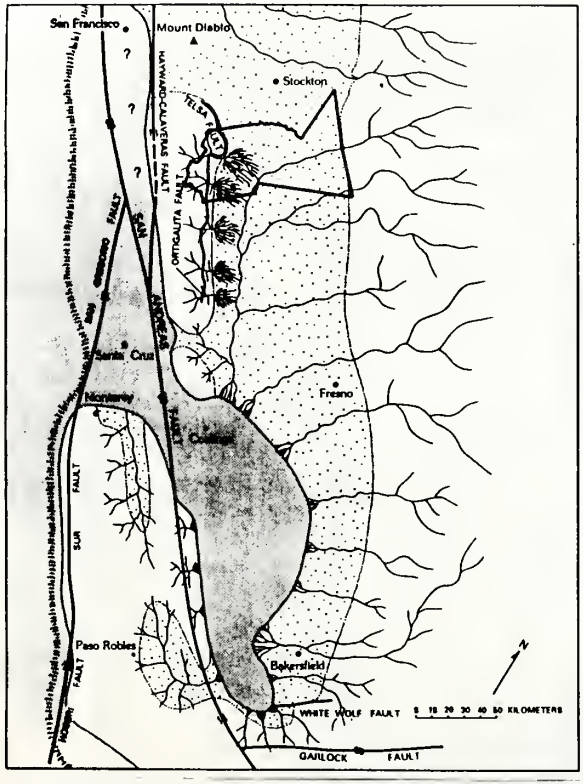


FIGURE 5h. – Pliocene (about 3-4 million years ago). See Figure 5a for explanation.

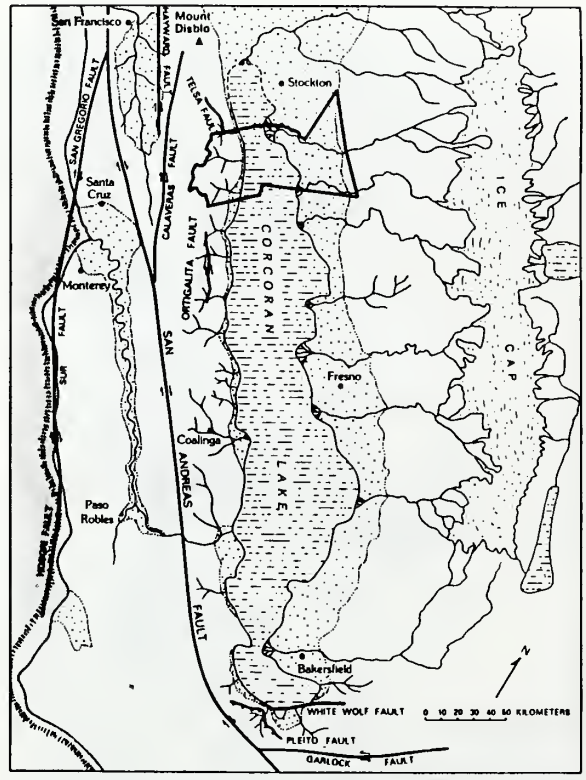


FIGURE 5i. – Pleistocene (about 0.6-0.7 million years ago). See Figure 5a for explanation.

STRATIGRAPHY

As shown in Figure 3, the stratigraphy of the county can be generalized into ten broad units. Each will be briefly described, with a summary of the formations that compose them. The unit symbols used here do not coincide with those shown on the geologic maps presented as Plates 1A, 1B, and 1C.

Jurassic Metavolcanic and Metasedimentary Rocks of the Sierra Nevada Foothills (Jm)

Exposed along the easternmost edge of Stanislaus County is a group of metamorphosed Jurassic igneous and sedimentary rocks that are interpreted to have formed in an oceanic island-arc environment about 155-160 million years ago (Schweickert and others, 1988). Assigned by Schweickert and others (1988) to a tectonostratigraphic unit called the "Foothills Terrane," these rocks were accreted to the North American continent by subsequent collision of the island arc with the continent during convergent plate motion. Thus, their present location is not the same as that in which they originally formed. The Foothills Terrane was then metamorphosed to greenschist facies about 155 million years ago during the Nevadan Orogeny (Schweickert and others, 1988; Schweickert and others, 1984; Mannion, 1960).

The main units that comprise this group are the Gopher Ridge Volcanics and the Merced Falls Slate. The Gopher Ridge Volcanics are mainly andesitic in composition, although there are some mafic rocks and substantial exposures of silicic rocks. The Merced Falls Slate, a local term for the regional Mariposa Formation, comprises mostly dark slate and minor graywacke sandstone, probably formed by submarine turbidites. In a few places, these rocks are intruded by small, younger Mesozoic plutons.

Aeromagnetic anomalies (Plate 10, Appendix C) suggest that this terrane extends in the subsurface far to the west of its exposed area.

Jurassic-Cretaceous Marine Sedimentary and Volcanic Rocks of the Franciscan Complex (JKf)

In the southwestern part of the county, within the Coast Ranges Province, are widely exposed coherent sedimentary-volcanic strata and melange of the Jurassic-Cretaceous Franciscan Complex. These rocks have been subdivided into two general tectono-stratigraphic terranes, the Cretaceous Burnt Hills and the more extensive Jurassic-Cretaceous Eylar Mountain (Blake, 1981; Blake and others, 1990; Bennison and others, 1991). The coherent strata are composed mainly of graywacke sandstone and siltstone-shale, deposited by submarine turbidity currents, with lesser amounts of chert and greenstone, all of which exhibit some degree of

metamorphism. The melange consists mainly of tectonic blocks of graywacke sandstone, chert, greenstone, glaucophane schist, and serpentinite in a sheared mudstone matrix. It appears that the majority of the Franciscan Complex in the county is melange. These characteristics are typical of the Franciscan Complex in general (Bailey and others, 1964; Blake and others, 1984), although the amount of chert in the coherent strata of the county is remarkable as will be described in a subsequent section.

In the Mount Oso area, Raymond (1973a) subdivided the Franciscan Complex into several "broken formations" and melange units. All of these are assigned to the Eylar Mountain Terrane as subunits on Plate 1A.

Rocks of the Franciscan Complex were originally formed offshore when clastic sediments were deposited in a trench developed on an oceanic plate, which was undergoing subduction beneath the North American continent (Bennison and others, 1991; Blake and others, 1990). Some of these rocks were accreted onto the continent during subduction and later elevated by continued tectonism.

Unrelated in age but of possible importance regarding mineralization is a group of small exposures of Tertiary volcanic rocks south of Mt. Stakes that are intruded as dikes into the Franciscan Complex. Radiometric dates on similar rocks south and west of this area give ages of 10-11 million years (Crawford, 1976; Clark Blake, U.S. Geological Survey, personal communication, 1992).

Jurassic Igneous Rocks of the Coast Range Ophiolite (Jc)

Closely associated with the Franciscan Complex are several pervasively faulted and sheared masses of igneous rock that comprise what is regionally termed the Coast Range Ophiolite (Hopson and others, 1981). Geologists generally agree that ophiolite represents oceanic crust and mantle material now exposed on land. For simplicity, we have also included in this unit several bodies of serpentinite in the Coast Ranges Province that are either fragments of Coast Range Ophiolite or tectonic blocks within melange of the Franciscan Complex.

Most prominent in this unit is what is locally termed the Del Puerto Ophiolite, which is exposed along the upper reaches of Del Puerto Canyon. Evarts (1977, 1978) has subdivided the Del Puerto Ophiolite into 3 main members termed, from bottom to top, the Alpine Peridotite Member, Plutonic Member, and Volcanic Member. Dated at about 150-160 million years old, the ophiolite is interpreted by Evarts (1978; personal communication, 1992) to have formed in an island arc. In contrast, Hopson and others (1981) believed it formed at a spreading ocean ridge.

Along Quinto Creek, southwest of Newman, is another fragment of Coast Range Ophiolite, described by Hopson and others (1981) to consist of ultramafic, plutonic, and volcanic rocks.

Jurassic-Cretaceous Marine Sedimentary Rocks of the Great Valley Sequence (JKgv)

East of and adjacent to the Franciscan Complex and originally deposited on top of the Coast Range Ophiolite is a thick sequence of marine strata termed the Great Valley Sequence. Composed mostly of marine sandstone, shale, siltstone, mudstone, and lesser amounts of conglomerate, this unit was deposited largely by turbidity currents during the Jurassic and Cretaceous on crystalline basement of the Sierra Nevada in the east part of the county and on Coast Range Ophiolite in the west part. It represents "forearc" or "arc-trench gap" deposits, which were emplaced between the magmatic arc of what is now the Sierra Nevada and an oceanic trench to the west. Specifically, this unit includes the Lotta Creek Tuff, Knoxville(?) Formation, Panoche Formation, Adobe Flat Shale Member of the Panoche, and Moreno Formation. The Lotta Creek Tuff is the basal stratum of the Great Valley Sequence and is unusual because it is composed of volcaniclastic material and chert.

A small exposure of rock on the northeast edge of the county, northwest of Knights Ferry, may be a remnant of the Great Valley Sequence.

Tertiary Volcanic Rocks - Table Mountain Latite (Tv)

In the vicinity of Knights Ferry is the exposed remnant of a Tertiary lava flow called the Table Mountain Latite. Dated at about 9 million years old (Slemmons, 1966), this flow is thought to have erupted near the crest of the present day Sierra Nevada around Sonora Pass. It then flowed down a river canyon, which emptied into the Great Valley. Because it is very dense and hard, it resisted erosion better than the adjacent, relatively soft rock of the river canyon. Consequently, the surrounding rock was removed, which left the lava flow high above the surrounding terrain. Known today as Table Mountain, this rock mass is spectacularly exposed in places from Knights Ferry northeastward along State Route 108/120.

Tertiary Volcanic and Sedimentary Rocks Associated with the Coast Ranges (Tc)

Along the northeastern edge of the Coast Ranges Province, adjacent to Interstate 5, is a narrow belt of northwest-striking Tertiary strata, which range in age from Paleocene to Pliocene (Bartow and others, 1985). They include both marine and nonmarine sedimentary rocks and minor volcanic rocks. The rocks were deposited in an environment that was shallow- to deep-marine

during the Late Paleocene and Eocene and nonmarine during the Late Oligocene to Pliocene (Bartow, 1991).

Specifically, this unit consists of the Tesla Formation, Domengine Sandstone, Kreyenhagen Shale, Poverty Flat Sandstone, Valley Springs Formation, Neroly Sandstone, and an unnamed formation of Tertiary fanglomerate.

Tertiary Volcanic and Sedimentary Rocks Derived from the Sierra Nevada (Ts)

Exposed in northeastern Stanislaus County are the erosional remnants of several Tertiary formations that record diverse depositional environments. Oldest is the Eocene Ione Formation, a paralic sequence of deltaic and fluvial sedimentary rocks (Bartow, 1992; Rodgers, 1986). Successively overlying the Ione unconformably are the volcanic and fluvial Oligocene-Miocene Valley Springs Formation and Miocene-Pliocene Mehrten Formation. These formations in turn are overlain by the alluvial Pliocene Laguna Formation and Plio-Pleistocene North Merced Gravel.

Quaternary Alluvium Derived from the Coast Ranges (Qc)

In southwestern Stanislaus County along the boundary of the Coast Ranges Province and Great Valley Province are extensive Quaternary alluvial sediments deposited by streams that drain from the Coast Ranges; most of the deposits are east of the range front and extend to the San Joaquin River.

The geomorphic form of these deposits is that of a bajada, or group of coalesced alluvial fans, formed where the streams discharge from the higher-relief Coast Ranges into the lower-relief Great Valley. Fans associated with the larger streams are more extensive but gentler sloped than those associated with the smaller streams, which tend to be steeper but much less extensive. Within the Coast Ranges, the streams tend to have channel and terrace deposits that are narrow, which reflects the generally steep canyons.

The composition of the alluvium varies from fan to fan, depending on size of the drainage basins and the type and hardness of the lithologies underlying the basins. Transport distances are relatively short and gradients relatively steep; consequently, the alluvium generally is not well-sorted, and clasts are commonly not well-rounded.

Quaternary Alluvium Derived from the Sierra Nevada (Qs)

In contrast to the relatively narrow strip of Quaternary alluvium derived from the Coast Ranges, the central and northeastern parts of the county are widely covered by broad alluvial fan, channel, and terrace deposits derived largely from

the Sierra Nevada (Marchand and Allwardt, 1981). From oldest to youngest, the components of this unit include the Turlock Lake Formation, Riverbank Formation, Modesto Formation, and post-Modesto (Holocene) alluvium.

This unit is mainly arkosic in composition, which reflects the granitic and metamorphic source rocks in the Sierra Nevada to the east. Most sediments were deposited by the present and ancestral Stanislaus and Tuolumne Rivers, which provided long transport distances through a terrain of hard basement rocks. This transport allowed for thorough reworking and sorting of the sediments such that they are cleaner and more well-rounded than the alluvial deposits associated with the Coast Ranges. Secondary drainages, such as Dry Creek and those north of Woodward Reservoir, commonly have sediments that are locally derived, such as from metamorphic and Tertiary volcanic rocks.

Quaternary Alluvium of Floodplains of the San Joaquin River, Lower Stanislaus River, and Lower Tuolumne River (Qsj)

Situated along the geomorphic axis of the Great Valley in southwestern Stanislaus County, this unit consists of Quaternary channel and floodplain deposits of the San Joaquin River, lower Stanislaus River, and lower Tuolumne River. Representing the lowest topography and lowest transport energy in the county, the sediments of this unit are generally finer-grained compared to the Quaternary alluvium of the adjacent fans that comprise the Qs and Qc units described above.

STRUCTURE

Knowledge of the structural framework of Stanislaus County is also important in understanding the distribution of mineral resources in the county. Structural attitudes of rock units and the character of contacts that juxtapose the units can influence the location of resources as well as the economics of mining them. Described below are the major large-scale structural features and characteristics of the county. Some of these are also described in Appendix C from a geophysical perspective.

Folds and Metamorphic Foliation

The Jurassic metavolcanic and metasedimentary rocks of the Foothills Terrane, exposed in the eastern part of the county, exhibit a fairly consistent regional metamorphic foliation that strikes northwest and generally dips steeply northeast (Clark, 1964; Mannion, 1960). Locally, dips are widely variable, however. The strata are interpreted to be tightly folded (Clark, 1964).

The Cenozoic sedimentary rocks deposited on the crystalline basement in the central and eastern parts of Stanislaus County appear to show little or no folding, depending on age. In this area, the sediments strike northwest and dip gently to the southwest. The dip is probably caused by both original deposition angle and gentle tilting related to uplift of the Sierra Nevada as a fault-block mountain range. This structural attitude has resulted in the progressive general exposure of the major Cenozoic formations, with oldest (Ione Formation) in the east and youngest (Modesto Formation) in the west. This pattern of exposure is important relative to location of mineral resources in this part of the county.

The Cenozoic sedimentary rocks become progressively thicker to the west away from the Sierra Nevada until they reach an interpreted maximum thickness of about 4,500 feet just east of the San Joaquin River (Bartow, 1985). In the subsurface, these sedimentary rocks unconformably overlie Cretaceous strata of the Great Valley Sequence, which together with the Cenozoic rocks, reach an interpreted thickness of at least 14,000 feet beneath the San Joaquin River. Approximately coincident with this location is the axis of the San Joaquin Valley Syncline, which represents large-scale deformation of both the Cenozoic sedimentary rocks and the Great Valley Sequence in this area (Figure 4). West of the axis, the sedimentary rocks are generally more steeply dipping than to the east, such that they crop out as a homocline of north- to northwest-trending strike ridges and valleys in the Coast Ranges. Generally, dips are steep to almost vertical in the exposed Great Valley Sequence. Additionally, the thickness of the Great Valley Sequence here is about twice that of those rocks present in the subsurface just to the east (Zoback and Wentworth, 1986). Locally, in the vicinity of Orestimba Creek, the dip of Cenozoic sedimentary rocks is gentle.

Within the Franciscan Complex, structural attitudes of sedimentary strata range from relatively consistent in the coherent units ("broken formations" of Raymond, 1973a) around Mt. Oso to chaotic and disrupted in the melange units. These characteristics are important in the discovery and mining of mineral deposits associated with the Franciscan Complex because of the requirement to determine lateral continuity of the deposits.

Although the Coast Range Ophiolite has been extensively dismembered by faulting, Evarts (1977, 1978) has mapped locally consistent attitudes in several of the units that make up the Del Puerto body. Dips of magmatic layering generally are moderate to steep in units of the Alpine Peridotite Member.

Faults

Three major fault zones (Tesla-Ortigalita, Coast Range, and San Joaquin) are known in Stanislaus County, along with numerous secondary faults present within the general geologic units described above.

The main boundary between the Franciscan Complex and the Great Valley Sequence is the Tesla-Ortigalita Fault Zone, which extends in sinuous form southeast across the county from Hospital Canyon in the north to Quinto Creek in the south. This fault zone is interpreted to be a steeply dipping complex of faults, with an overall sense of reverse movement with some right-lateral motion (Bartow, 1991; Raymond, 1973b). Although its history is poorly understood, this complex appears to be largely Cenozoic in age; it is interpreted to have thrust Franciscan Complex eastward over Great Valley Sequence and Coast Range Ophiolite (Raymond, 1973b; Bartow, 1991; Blake and Showalter, 1991).

Locally, remnants of the Coast Range Fault (previously termed the "Coast Range thrust" by Bailey and others, 1970) form the boundary between the Franciscan Complex and Coast Range Ophiolite (Raymond, 1973b; Platt, 1986; Harms and others, 1992). Geologists have considered this fault, which extends over much of the length of the California Coast Ranges, to represent the original tectonic boundary between the North American Plate, carrying Great Valley Sequence and Coast Range Ophiolite, and a subducting oceanic plate, carrying Franciscan rocks. Recently, Platt (1986) proposed a model in which the present Coast Range Fault is not a simple subduction-zone thrust, but rather, is a composite of the displaced and reactivated original thrust surface and younger low-angle extensional faults. This fault complex developed by continued subduction and underplating beneath the Franciscan accretionary wedge at least into the Paleocene. A result of the tectonic extension was the structural unroofing and uplift of deep-seated high-pressure/low-temperature metamorphic rocks of the Franciscan. Harms and others (1992) have interpreted the contact between the Coast Range Ophiolite and Franciscan Complex on the south flank of Red Mountain to be one of the detachment-like extensional faults.

It is not clear what parts of the Tesla-Ortigalita Fault Zone may actually be reactivated segments of the Coast Range Fault, assuming that the Tesla-Ortigalita is much younger. The importance of the two zones is their apparent influence on mercury-gold mineralization as will be described in Part IV.

Along the boundary between the Coast Ranges Province and the Great Valley Province is the concealed San Joaquin Fault, a steeply dipping reverse fault (Bartow, 1991), which subparallels Interstate 5 and is apparently responsible for the abrupt change in topography between the provinces. It may be as young as

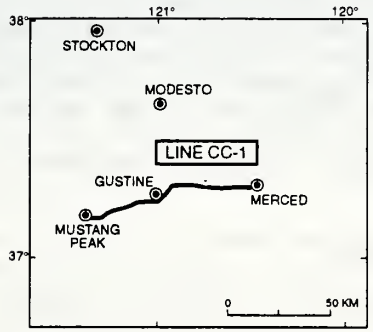
Holocene (Jay Noller, Lettis and Associates, personal communication, 1992). Its effect on the thickness of sand and gravel deposits associated with the Quaternary alluvium is poorly known; however, it is conceivable that the inferred up-to-the-west motion may have enhanced deposition of coarse sediments to the east of the fault zone.

Secondary faults are exposed within each of the main geologic units, except in the center of the county. In the east, Mannion (1960) mapped a few east-west-trending faults in the Sierran metamorphic terrane. In the west, the Franciscan Complex and Coast Range Ophiolite are riddled with faults that reflect their turbulent emplacement on the North American continent by accretion and subsequent dismemberment. In contrast, the Great Valley Sequence and Tertiary strata show relatively minor faulting internally, most of it striking northerly.

To interpret the geologic structure and character of the basement rock in the subsurface of Stanislaus County, various geophysical techniques and drill-hole data have been used. Gravity and aeromagnetic data (Plates 9, 10; Appendix C; Zoback and Wentworth, 1986) suggest that the boundary between Sierra Nevada crystalline basement and Great Valley (oceanic crust?) crystalline basement follows a northwest-trending line beneath Hughson and Denair. To the southwest, an east-west seismic-reflection profile between Mustang Peak and Merced (Zoback and Wentworth, 1986; Wentworth and others, 1984) suggests that the Franciscan Complex has been thrust eastward as a duplex-like wedge between the Great Valley Sequence above and the Great Valley basement below (Figure 6). This movement may explain the major up-turning and abrupt thickening the Great Valley Sequence in the Coast Ranges. Analysis of aeromagnetic data (Plate 10; Zoback and Wentworth, 1986) suggests a large, concealed body of serpentinite also in this area (Figure 6). To the northwest, other large magnetic anomalies (Red Mountain-Del Puerto and Orestimba Creek on Plate 10) could represent bodies of serpentinite and ultramafic rock that are much more extensive in the subsurface than is indicated by surface exposure (Appendix C).

DISTRIBUTION OF MINERAL DEPOSITS RELATIVE TO GEOLOGY

Because of the diverse geology of Stanislaus County, as described above, there is a distinct clustering of a variety of mineral deposits throughout the county. Listed below are different geologic units and structures with the main mineral commodities known or suspected to be associated with them. The characteristics and uses of each of these commodities are described in Part III of this report (General Application of Mineral Land Classification to Stanislaus County).



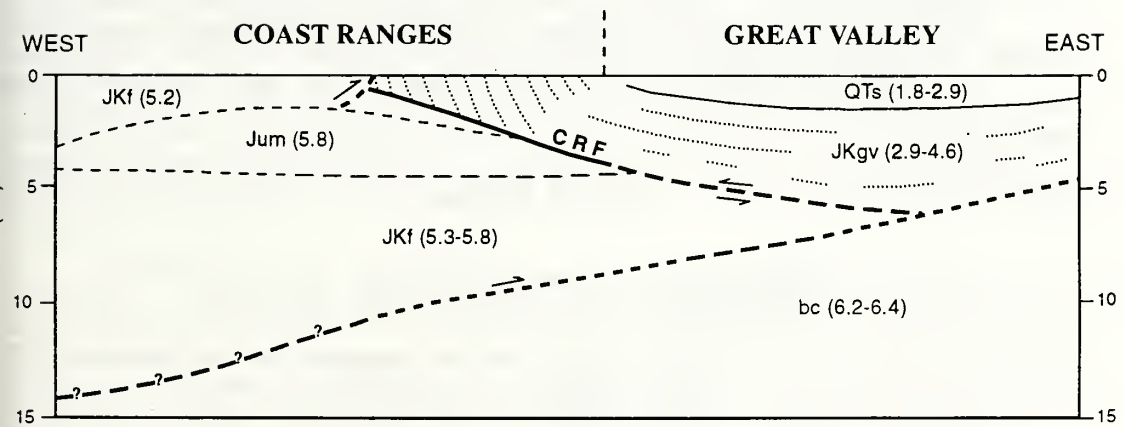


FIGURE 6. – Geologic cross section interpreted from seismic reflection profile CC-1 in southwestern Stanislaus County. Geologic units are the same as in Figure 4. Numbers in parentheses are the ranges of seismic velocities of the units, recorded in km/sec. Thick lines are faults; arrows show sense of movement. Dashed lines are boundaries of the inferred body of serpentinite. Dotted lines represent dips of strata in Great Valley Sequence. CRF–Coast Range Fault. No vertical exaggeration. Modified from Zoback and Wentworth (1986).

Western Part of County

Quaternary Alluvium - Sand and Gravel
(fan, levee, channel deposits)
Valley Springs Formation - Clay?
Poverty Flat Sandstone - Specialty Sand, Clay
Kreyenhagen Shale - Diatomite
Tesla Formation - Specialty Sand
Great Valley Sequence - Dimension Stone, Expansible Shale
Coast Range Ophiolite - Chromite, Magnesite, Crushed Stone
Franciscan Complex - Manganese, Mercury, Crushed Stone
Serpentinite - Magnesite, Chromite, Mercury
Tesla-Ortigalita Fault Zone and Vicinity - Mercury, Magnesite, Gold?
Coast Range Fault - Mercury, Magnesite, Gold?

Eastern Part of County

Quaternary Alluvium - Sand and Gravel, Gold, Silver
(tailings, Post-Modesto alluvium, Modesto Formation)
Table Mountain Latite - Crushed Stone
Valley Springs Formation - Clay?
Ione Formation - Clay, Specialty Sand, Dimension Stone
Jurassic Metavolcanic Rocks - Copper, Zinc, Lead, Gold, Silver, Crushed Stone, Clay
Jurassic Metasedimentary Rocks - Gold, Silver, Crushed Stone

MINING HISTORY

"Stanislaus County is not prolific in its extractive resources."

- Stanislaus County Department of Planning and Community Development (1990)

Despite the above statement, Stanislaus County has had a diverse and productive mining history. Commodities from each of the three main categories of mineral resources, construction aggregate, industrial, and metallic, have been produced since the 1800s. Value of total production of all mineral commodities in the county is estimated at several hundred million dollars (1993 prices). Most valuable among these commodities are aggregate and gold. Gold alone amounts to at least $100,000,000. Today, the only mineral commodity mined in the county is construction aggregate in the form of sand and gravel.

METALLIC MINERALS

The first serious mining in Stanislaus County began with the search for metallic mineral resources in the middle and late 1800s. Gold was the most sought-after commodity, with the main activity concentrated in the eastern part of the county. Although there are no known lode gold mines, placer mining was extensive, particularly around Knights Ferry and La Grange. Some of the more important localities of placer mining are shown on Plate 8C and listed in Appendix A. Manual and hydraulic methods were used at first, but dredging of channel deposits along the Tuolumne and Stanislaus Rivers, as well as from several secondary drainages and older alluvial deposits, later became the principal method of mining gold in the county. Total estimated production of gold in the county through 1959 was 364,600 ounces (Koschmann and Bergendahl, 1968).

The most important period of dredging was 1910-1950, when a dredge of the La Grange Gold Dredging Company operated along the Tuolumne River from La Grange to about 9 miles downstream. This dredge has the distinction of the longest continuous operation of any in California; it began activity in 1907 and terminated in 1951 (Charles, 1947; Clark, 1970). The La Grange dredge excavated more than 70,000,000 cubic yards (Charles, 1947) of sediment to depths of as much as 60 feet. Also produced were silver and platinum. Another important dredge was the Tuolumne, which began operation in 1938 and continued at least into the 1940s (Anonymous, 1946). It operated a few miles south of La Grange and today is part of an undeveloped county park south of Dawson Lake. Dredging was also active into the 1940s along the Stanislaus River from Knights Ferry to near Oakdale, and in the northernmost tip of the county.

Other metallic commodities mined in the county include chromite, manganese, and mercury. Chromite was first discovered and mined in 1916 at Del Puerto Canyon (Hawkes and others, 1942). Mining continued through the end of World War I, stimulated by high prices and construction of a railroad from Patterson to the vicinity of Hideout Canyon. During World War II and the Korean War, chromite was again mined, supported by a Federal price-guarantee program. The last known production was in 1958. Total production of both shipping-grade and milling-grade ore was likely less than 10,000 tons.

Manganese was probably discovered in the 1800s in the Coast Ranges of Stanislaus County, mainly around Mount Oso. Here, many properties were prospected and some developed, most notably the Buckeye, Liberty, and Tip Top Mines (Trask and others, 1950). The Buckeye Mine is reputed to be the second largest producer of manganese in California. Manganese was produced mainly during World Wars I and II and briefly in the 1950s. Cumulative

production is estimated at nearly 40,000 tons of ore (Trengove, 1960).

Mercury (quicksilver) was discovered at least as early as the 1870s and 1880s at several locations in the Coast Ranges of the county (Hawkes and others, 1942). Production was minor, however, compared to many other areas of California; total production is probably only a few hundred flasks. The most productive property is believed to be the Phoenix (Summit) Mine, which is in the headwaters area of Del Puerto Canyon.

INDUSTRIAL MINERALS

Several industrial minerals have been produced in Stanislaus County, including clay, diatomite, magnesite, mineral pigment (yellow ochre), quartz (silica), and dimension stone.

A type of kaolinitic clay, termed "ball" clay, is one of the more valuable industrial minerals that has been produced in the county. Probably first mined about 1929-1930 in the Knights Ferry area, this commodity has been extracted from several sites in the Ione Formation of the Sierra Nevada foothills. Mining continued at least until the middle 1980s. Cumulative production is many thousands of tons. Common clay was also mined near several towns for the manufacture of brick.

Diatomite has been mined in the area west of Newman, at least since the 1940s (Davis, 1951). Here, several open pits have produced tens of thousands of tons of a low-grade material over the years for use in several applications. The most recent mining ceased in the late 1980s.

Stanislaus County has been one of the most important producers of magnesite in California (Ver Planck, 1957). First discovered about 1915, this commodity was extracted from two important districts, the Red Mountain and Bald Eagle, both in the Coast Ranges. Production ceased in World War II, because of exhaustion of some of the known ore and because of development of a sea-water conversion process to produce magnesia (Ver Planck, 1957). Cumulative production was probably a few hundred thousand tons.

Mineral pigment, in the form of yellow ochre, was mined in the Knights Ferry area, at least since the early 1900s (Aubury, 1906). Generally used in the paint industry, this commodity was probably produced in quantities of no more than a few thousand tons total.

In Del Puerto Canyon, a quartz-calcite vein complex provided both silica for the steel industry and quartz for the U.S. Bureau

of Standards in 1943 (Charles, 1947). It is not known to have been active since then.

The Ione Formation of eastern Stanislaus County has been a source of dimension (building) stone since the 1800s (Aubury, 1906). Here, horizons of variegated, well-cemented sandstone have been quarried at several localities. Some workings appear to have been active fairly recently, perhaps as sources of decorative rock. Also, some quarrying of slate took place in the metamorphic rock upstream from La Grange. Total production in the county is not known; known quarries are small.

CONSTRUCTION AGGREGATE

As we casually use sidewalks, roads, and school and office buildings, it is easy to overlook the economic impact this commonplace construction material has had on the development of Stanislaus County since the 1849 Gold Rush. Several of the applications of this material in the county are described below.

Construction sand and gravel has been extensively mined from the Stanislaus and Tuolumne Rivers, as well as other streams within Stanislaus County since the 1860s. As the population of the county grew, consumption of sand and gravel also grew. Today, aggregate mined from river terraces and stream channels is still the primary source of construction materials within the county.

With the arrival and subsequent growth of railroads in Stanislaus County during the late 1870s, aggregate mined from the Tuolumne, Stanislaus, and other streams in the San Joaquin Valley was used extensively as railroad ballast and railroad sand. Railroad sand, used for braking, was mined from pits in terraces along the Stanislaus River north of Riverbank.

In the mid 1920s, sand and gravel was extracted from the Atlas-Olympia Rock Company pits along the Stanislaus River, where Kerr Park is today, and shipped via railroad cars for use in construction of the O'Shaughnessy Dam at the Hetch Hetchy Reservoir in Yosemite National Park. As many as 12 to 14 rail cars left the mine daily.

County roads in the mid 1800s were little more than trails that ran between gold mining camps, and were frequently impassible during the wet winter months. As the population grew from the increase in farming, ranching, and gold mining, these early roads were gradually improved by leveling and surfaced with gravel. Road ballast was routinely extracted from local river channels during the late 1800s. In the early 1900s, gravel sections of roads were sprayed with an oil overcoat to reduce dust. With the advent of modern road-construction machinery and improved petroleum products during the late 1910s and early

1920s, some of the more heavily traveled roads in the county were coated with asphaltic materials (Haswell, 1981). The use of asphalt-surfaced roads gradually expanded throughout the county.

The first concrete roads within the county were constructed in the early 1920s. One of the earliest, the "Waterford Road," connected Modesto and Waterford. It was 16-feet wide, had a posted speed limit of 35 miles-per-hour and today forms part of State Route 132 (Haswell, 1981).

The first large-scale concrete project within the county was the construction of La Grange Dam on the Tuolumne River. During construction of the dam, about 3,000 barrels of cement were shipped from Germany, mixed with local sand and gravel to form concrete, and used to mortar the large rock blocks of the dam. When completed in 1893, it was the highest overflow dam in the United States at 128 feet high and 90 feet thick at the base (Elias, 1924).

A common problem with early earthen irrigation canals was the constant burrowing by ground squirrels and other rodents, which caused the canals to quickly deteriorate. As concrete became a more common construction material in the 1920s and 1930s, it was found that concrete-lined canals required much less maintenance. These eventually replaced most of the larger earthen canals in the county.

The dredge tailings in eastern Stanislaus County are increasingly being used as construction aggregate, although they are neither as easy to mine nor as profitable as undredged sand and gravel deposits. One notable use of the tailings was in the construction of the earth-fill New Don Pedro Dam, a few miles east of Stanislaus County on the Tuolumne River. In the late 1960s and early 1970s, giant 70-ton "belly scrapers" scalped about 16 million tons of dredge tailings from the Tuolumne River near La Grange for use in the dam.

PART II

CALIFORNIA MINERAL LAND CLASSIFICATION SYSTEM

PART II - CALIFORNIA MINERAL LAND CLASSIFICATION SYSTEM

CONCEPT AND DEFINITION OF MINERAL RESOURCE ZONES

Areas subject to California Mineral Land Classification studies are divided by the State Geologist into various Mineral Resource Zone (MRZ) categories that reflect varying degrees of mineral potential. The MRZ nomenclature and criteria adopted by the California State Mining and Geology Board (1983) are graphically portrayed on what is referred to as the California Mineral Land Classification Diagram (Figure 7). Definitions of terms used in the diagram are included in this section. The diagram is a modification of a mineral resource classification scheme developed by the U.S. Bureau of Mines and the U.S. Geological Survey (1980) that presents a relationship between mineral resource occurrence and economic significance. The horizontal axis of the diagram represents the degree of knowledge about mineral occurrence, and the vertical axis portrays economic characteristics of mineral deposits (grade and size). The diagram may be divided into four parts for the purpose of presenting basic information regarding mineral resource potential of land:

1) **Areas of No Mineral Resource Significance**
2) **Areas of Identified Mineral Resource Significance**
3) **Areas of Undetermined Mineral Resource Significance**
4) **Areas of Unknown Mineral Resource Significance**

As shown in Figure 7, each of the above four divisions relates directly to and incorporates one of the four basic Mineral Resource Zone (MRZ) categories established through law and/or State Mining and Geology Board policy. The specific definitions of each MRZ category are given below. Note in both Figure 7 and in the MRZ definitions below that two of the categories (MRZ-2 and MRZ-3) are divided into two subcategories.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources.

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. As shown on the California Mineral Land Classification Diagram, MRZ-2 is divided on the basis of both degree of knowledge and economic factors. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure, and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits.

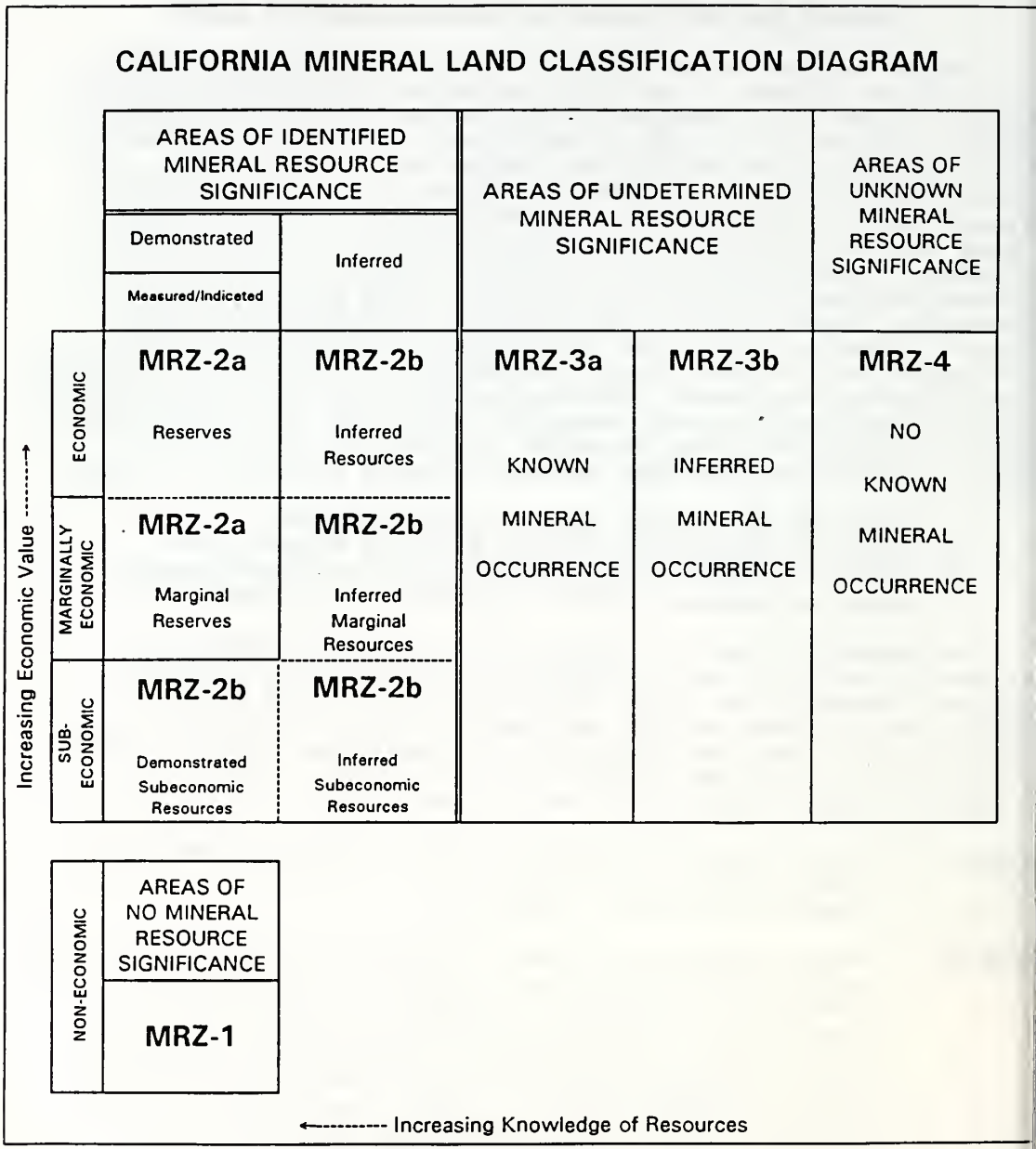


FIGURE 7. – California Mineral Land Classification Diagram. Diagrammatic relationship of mineral resource zone (MRZ) categories to the resource/reserve classification system. Adapted from U.S. Bureau of Mines and U.S. Geological Survey (1980).

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are sub-economic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Areas containing known mineral occurrences of undetermined mineral resource significance. Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories. As shown on the California Mineral Land Classification Diagram, MRZ-3 is divided on the basis of knowledge of economic characteristics of the resources.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources.

The distinction between the MRZ-1 and MRZ-4 categories is important for land-use considerations. It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence. Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

NOMENCLATURE OF THE MINERAL LAND CLASSIFICATION SYSTEM

Listed below are definitions of the nomenclature associated with the California Mineral Land Classification Diagram. It is important to refer to these definitions when studying the different resource categories shown on the California Mineral Land Classification Diagram. Particular attention should be given

to the distinction between a mineral deposit and a resource and to how a mineral deposit may relate to resources.

MINERAL DEPOSIT: A mass of naturally occurring mineral material, e.g., metal ores or nonmetallic minerals, usually of economic value, without regard to mode of origin. The mineral material may be of value for its chemical and/or physical characteristics.

MINERAL OCCURRENCE: Any ore or economic mineral in any concentration found in bedrock or as float; especially a valuable mineral in sufficient concentration to suggest further exploration.

ECONOMIC: This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

MINERAL RESOURCE: A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible. The terms resource and mineral resource are synonymous in this report.

RESERVES: That part of the resource base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. In the case of aggregates the term includes only permitted resources.

IDENTIFIED MINERAL RESOURCES: Resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified mineral resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into demonstrated and inferred.

DEMONSTRATED: A term for the sum of measured plus indicated.

MEASURED: Quantity is computed from dimensions revealed in outcrops, trenches workings, or drill holes; grade and/or quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the

geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

INDICATED: Quantity and grade and/or quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are further apart or otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

INFERRED: Estimates are based on an assumed continuity beyond measured and/or indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

MARGINAL RESERVES: That part of the demonstrated reserve base that, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technologic factors.

MARGINAL RESOURCES: That part of the inferred resource base that, at the time of determination, would be economically producible, given postulated changes in economic or technologic factors.

SUBECONOMIC RESOURCES: The part of identified resources that does not meet the economic criteria of marginal reserves and marginal reserves.

CRITERIA USED IN MINERAL LAND CLASSIFICATION

To be considered **significant** for the purpose of Mineral Land Classification, a mineral deposit, or a group of mineral deposits that can be mined as a unit, must meet marketability and threshold value criteria adopted by the California State Mining and Geology Board (1983, p. 25-26). The criteria vary for different minerals depending on (1) whether they are strategic or non-strategic minerals, (2) their uniqueness or rarity, and (3) their commodity-type category (metallic minerals, industrial minerals, or construction minerals). For example, to be considered significant, the threshold value of the first marketable product for a metallic ore deposit is 500,000 1978 dollars, 1,000,000 1978 dollars for an industrial mineral deposit, and 5,000,000 1978 dollars for a construction aggregate

deposit. These figures were multiplied by 2.32 (California Department of Employment Development, personal communication, 1993) to calculate threshold values in October, 1993 dollars. The results are:

Metallic	$ 1,160,000
Industrial Minerals	$ 2,320,000
Construction Aggregate	$11,600,000

RELATIONSHIP OF CLASSIFICATION TO CLASSES OF MINERAL DEPOSITS

Mineral land classification is based upon both recognition and delineation of geologic environments present in an area and on determination of the types of mineral deposits likely to be hosted in those environments. Consideration is given to all non-fuel minerals of economic importance by determining what classes of mineral deposits are likely to be present in the area. In all, twelve distinct classes of mineral deposits are recognized (Table 1). Ten classes represent genetic type. The remaining two, construction aggregate and industrial minerals, are classified by groups of commodities because the resources in these groups typically have formed by diverse geologic processes.

Only those classes of deposits for which direct or indirect evidence indicates the presence or likely presence of significant mineral occurrences are addressed in the mineral land classification report. However, other types of mineral occurrences may be present, which, because of lack of evidence, are not presently recognized.

BY GENESIS
Bacteriogenic
Contact Metasomatism
Evaporation
Hydrothermal (exclusive of volcanogenic)
Magmatic Segregation
Mechanical Concentration (transported)
Metamorphism
Residual Concentration (in place)
Sedimentation
Volcanogenic (exhalative)
BY COMMODITY
(formed by diverse geologic processes)
Construction Aggregate
Industrial Minerals

TABLE 1. Classes of mineral deposits.

PART III

GENERAL APPLICATION OF MINERAL LAND CLASSIFICATION TO STANISLAUS COUNTY

PART III - GENERAL APPLICATION OF MINERAL LAND CLASSIFICATION TO STANISLAUS COUNTY

All land within Stanislaus County (Figure 1) has been classified for the presence or likely occurrence of construction aggregate, industrial, and metallic mineral resources according to both class of mineral deposit and mineral commodity. In addition, a small portion of San Joaquin County, adjacent to the Stanislaus River, has been classified for construction aggregate.

Of the 12 classes of mineral deposits listed in Table 1, six apply to classification of land in Stanislaus County (Table 2). A general overview of characteristics of each of these six classes is presented below, including pertinent general information regarding classification. Also included are properties and uses of the more important known and potential mineral commodities in the county that are associated with them. The uses are mainly taken from the U.S. Bureau of Mines (1993).

CONSTRUCTION AGGREGATE

Construction aggregate is essential to fulfill the needs of a modern society and is a resource of great importance to the economy of any urbanizing area. Sand, gravel, and crushed stone are collectively referred to as "construction aggregate" or simply "aggregate." When washed and sorted by size, aggregate can be used in a myriad of construction materials. When mixed with cement, aggregate provides bulk and strength to portland cement concrete, mortar, plaster, gunite and stucco. When crushed and mixed with bituminous materials, it is used to make asphalt, or more correctly, "asphaltic concrete." When used by itself, aggregate is processed for use as road base, subbase, railroad ballast, and as grading material--called "fill"--used in earthen dams and for preparing foundations at construction sites. Aggregate normally provides from 80 percent to 100 percent of the material volume in the above uses.

There are numerous reclaimed borrow pits throughout Stanislaus County. Aggregate extracted from these pits was most commonly used for fill, railroad ballast, subbase and base. Because such materials are plentiful in Stanislaus County, they are not classified in this report.

Special emphasis is given to aggregate that meets the specifications used in making portland cement concrete (PCC) and asphaltic concrete (AC). Such aggregate is called "concrete aggregate" or "concrete-grade aggregate" in this report. The material specifications for PCC and AC aggregates are more restrictive than the specifications for aggregate used in other applications. Deposits that are acceptable for use as PCC or AC

CLASS	NOTATION
Construction Aggregate (sand and gravel)	sg
Construction Aggregate (crushed stone)	cs
Hydrothermal	h
Industrial Minerals	i
Magmatic Segregation	m
Volcanogenic and Volcanogenic-Sedimentary	v

TABLE 2. Classes of mineral deposits applicable to Stanislaus County. Also shown are notations used in MRZ superscripts for each class. The volcanogenic-sedimentary class represents deposits that have not been conclusively demonstrated to be formed by one process or the other.

aggregate are the rarest and most valuable of aggregate resources. Aggregate produced from concrete-grade aggregate deposits can be, and is commonly, used in other lower quality products. Because of this versatility, value, importance in construction, and relative scarcity, concrete-grade aggregate deposits are of major concern when planning for future availability of aggregate commodities.

Rarely is in-place aggregate (raw material) physically or chemically suited for every type of aggregate use. Every potential deposit must be tested to determine how much material can meet specifications for a particular use, and what processing is required. Specifications for various uses of aggregate material have been established by several agencies, such as the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and the California Department of Transportation, to ensure that aggregate is satisfactory for specified uses. These agencies and other major consumers of aggregate test aggregate for acceptance by standard test procedures defined by such organizations as the American Society for Testing Materials and the American Association of State Highway Officials.

Most aggregate specifications have been established to ensure the manufacture of strong, durable materials capable of withstanding the physical and chemical effects of weather and use. For example, specifications for PCC and concrete products limit the use of aggregate materials containing gypsum, pyrite, zeolite, opal, chalcedony, chert, siliceous shale, volcanic glass, and some high-silica volcanic rocks. Gypsum lengthens the setting time of portland cement, pyrite dissociates to yield sulfuric acid and iron oxide stain, and other substances contain silica in a form that reacts with alkali substances in the cement, resulting in cracks and "pop-outs." Alkali reactions in portland cement concrete can be minimized by the addition of pozzolanic admixtures such as fly ash.

Specifications also call for precise particle-size distributions for the various uses of aggregate. Aggregate is commonly classified into two general sizes, coarse and fine. Coarse aggregate is rock retained on a 3/8-inch (or a #4 U.S.) sieve. Fine aggregate passes a 3/8-inch sieve and is retained on a #200 U.S. sieve (a sieve with 200 weaves per inch.) For some uses, such as asphaltic paving, particle shape is specified. The Standard Specifications issued by the California Department of Transportation (1988) require that at least 90 percent by weight of coarse aggregate (1/4-inch to 3/4-inch diameter) that is used as asphalt aggregate shall be crushed particles. Crushed stone is preferable to natural gravel in AC because asphalt adheres better to broken surfaces, and the interlocking of angular particles strengthens the AC.

The preferred use of one aggregate material over another in construction practices depends not only on specification standards, but also on economic considerations. Alluvial gravel is preferred to crushed stone for portland cement concrete aggregate because the rounded particles of alluvial sand and gravel result in a wet mix that is easier to work than a mix composed of angular fragments. The workability of a mix consisting of portland cement with crushed stone aggregate can be improved by adding more sand and water, but more cement must then be added to the mix to maintain concrete durability standards. At the present time, the additional cement amounts to about a quarter of a 94-pound sack per cubic yard of concrete at an additional cost of about $1.00 per cubic yard of mix. Although more care is required in pouring and placing a wet mix containing crushed stone, PCC made with this aggregate is as satisfactory as that made with alluvial sand and gravel of comparable rock quality.

PROCEDURES FOR CLASSIFYING CONSTRUCTION AGGREGATE

Aggregate Mineral Resource Zones within Stanislaus County are presented on three 1:48,000-scale maps (Plates 2A, 2B and 2C). These zones were established on the basis of an aggregate appraisal that included the following tasks for assessing the quality, quantity, and areal extent of aggregate deposits:

1. Examination of relevant geologic maps, aerial photos, geologic literature, and confidential aggregate industry data, such as drill logs and aggregate engineering test data.

2. Conferences with aggregate operators, earth scientists in academia, geologic consultants, and knowledgeable government representatives concerning aggregate-related issues.

3. Compilation and analysis of water well-log data from the California Department of Water Resources.

4. Field investigations of proposed, active, and depleted aggregate quarries, including field studies of rock exposures that are representative of geologic units that occur within Stanislaus County.

A portion of the Stanislaus-San Joaquin County boundary line follows the center of the Stanislaus River from one mile northwest of Riverbank westward for 20 miles to the confluence of the Stanislaus and San Joaquin Rivers. For purposes of geologic continuity and simplicity, a thin strip of southern San Joaquin County within and bordering the Stanislaus River was included in this report, as shown on Plates 1A, 1B and 1C. This included area covers approximately 50 square miles and represents about 3

percent of the total land area in Stanislaus County. This area is included in the classification process of this report and, for simplicity, is referred to henceforth as part of "Stanislaus County."

Areas Classified MRZ-2a or MRZ-2b

SMARA guidelines set forth two requirements to be used to determine if land should be classified MRZ-2a or MRZ-2b for aggregate:

1. The deposit must be composed of material that is suitable as a marketable aggregate commodity.

2. The deposit must meet the threshold value. The projected value (gross selling price) of the aggregate deposit, based on the value of the first marketable product, must be at least $11,600,000 (which equates to 5 million 1978-dollars). The average price of processed concrete sand and gravel in Stanislaus County is $6.50 per ton at the plant site (F.O.B.). The F.O.B. price of $6.50 per ton equates to about 1.8 million tons when correlated with the threshold value of $11,600,000.

Special emphasis is given aggregate that meets the engineering specifications for portland cement concrete (PCC) and asphaltic concrete (AC) in this study. Areas classified as MRZ-2a or MRZ-2b contain PCC-grade aggregate and/or AC-grade aggregate. PCC and/or AC are termed "concrete-aggregate" in this report. Deposits that are acceptable for use as PCC or AC aggregate are the rarest and most valuable of aggregate resources. Such areas contain resources that are either proven concrete grade or highly probable to be concrete-grade aggregate. The difference between deposits classified MRZ-2a and MRZ-2b is the degree of knowledge.

Areas classified as MRZ-2a are known to contain economic concrete aggregate deposits, based on drilling records, aggregate engineering test data, surface exposure analyses, mine information, and/or have a proven concrete performance history. Areas classified as MRZ-2b are inferred to contain economic concrete aggregate deposits, based on geologic interpretation of more limited data. Aggregate deposits in untested, unproven areas identified as MRZ-2b are believed to contain concrete-grade aggregate for either of the following reasons:

1. The aggregate in unproven areas is similar in age, lithology, and depositional environment to that of aggregate in areas classified as MRZ-2a and which contain proven concrete-grade aggregate.

2. The unproven deposit is a lateral extension of an alluvial formation from which concrete-grade aggregate has been produced.

TRANSPORTATION RATES

In Stanislaus County, the average bulk price of processed concrete-mix aggregate is about $6.50 per ton at the plant site (January 1993). However, this selling price reflects only part of the cost to the consumer. Transport cost is a significant part of the final delivery price. In areas lacking nearby aggregate sources, delivery charges alone may be greater than the sale price of the material at the plant site. Because it is a low-value, high bulk-weight commodity, a major part of the cost of aggregate to the consumer is for transportation. In fact, transport cost is the principal constraint defining the market area for a specific production district.

All aggregate marketed in Stanislaus County is transported by truck. Minimum rates for independent aggregate truckers are set by the California Public Utilities Commission (PUC). Rates for Stanislaus County and the surrounding region are published in "Minimum Rate Tariff 7-A," Sections 2 and 3. Charges are calculated based on either an hourly rate (Table 3) or a distance rate (Table 4). The minimum hourly rate or the minimum distance rate, whichever is larger, may be charged to the consumer. If the hourly rate is used, the carrier and debtor must enter into a written agreement prior to transport.

Table 4 shows how the PUC rates increase with distance as specified in Minimum Rate Tariff 7-A. To illustrate the economic importance of maintaining accessible local sources, hauling aggregate from Orestimba Creek Fan to Patterson (a distance of approximately 11.5 miles) results in an additional cost of about $1.71 per ton over the cost of the same material purchased F.O.B. at the mine site. In contrast, to haul aggregate to Patterson from the Tuolumne River production area east of Modesto (a distance of about 25.5 miles) would cost approximately $3.07 per ton, an increase of $1.36 more per ton to transport.

INDUSTRIAL MINERALS

Traditionally, industrial minerals are defined as those naturally occurring earth materials exclusive of metallic ores, fuels, or gemstones. These materials have economic value because of their physical and/or chemical properties. Bates (1960) classified the industrial minerals into two groups: Industrial rocks and industrial minerals. Division of the two groups is based on criteria such as tonnage produced, price per unit, proximity to markets, geologic occurrence and distribution, and

Table 3. Minimum hourly rates for transport of aggregate in Stanislaus County. Data taken from: Public Utilities Commission of the State of California, 1992, Minimum Rate Tariff 7-A (current rates as of December 3, 1992).

TYPICAL TONS PER LOAD	NO. OF AXLES PER UNIT OF EQUIPMENT	HOURLY RATES* ($)	$/TON/HR
10	2	43.49	4.35
15	3	49.21	3.28
24	4	50.93	2.12
26	5+	54.88	2.11

*Rates are higher for work done on holidays and weekends.

Table 4. Minimum distance rates for transport of aggregate in Stanislaus County. Data taken from: Public Utilities Commission of the State of California, 1992, Minimum Rate Tariff 7-A (current rates as of December 3, 1992).

MILES		RATES*	MILES		RATES*
OVER	BUT NOT OVER	$/TON	OVER	BUT NOT OVER	$/TON
0	1	0.55	35	36	3.98
1	2	0.65	36	37	4.07
2	3	0.76	37	38	4.17
3	4	0.87	38	39	4.26
4	5	0.97	39	40	4.34
5	6	1.08	40	41	4.43
6	7	1.19	41	42	4.53
7	8	1.29	42	43	4.62
8	9	1.40	43	44	4.71
9	10	1.51	44	45	4.79
10	11	1.62	45	46	4.89
11	12	1.71	46	47	4.98
12	13	1.82	47	48	5.07
13	14	1.91	48	49	5.17
14	15	2.02	49	50	5.26
15	16	2.11			
16	17	2.21	50	52	5.43
17	18	2.30	52	54	5.59
18	19	2.39	54	56	5.77
19	20	2.50	56	58	5.94
20	21	2.59	58	60	6.11
21	22	2.68			
22	23	2.78	60	63	6.31
23	24	2.87	63	66	6.58
24	25	2.98	66	69	6.85
25	26	3.07	69	72	7.12
26	27	3.16	72	75	7.38
27	28	3.26	75	80	7.79
28	29	3.35	80	85	8.18
29	30	3.43	85	90	8.60
30	31	3.52	90	95	9.01
31	32	3.62	95	100	9.42
32	33	3.71			
33	34	3.82			
34	35	3.84			

* Rates are higher for holidays and weekends.

processing. The industrial rocks are usually economic in large tonnages, low price per unit, close proximity to markets, and require only minor processing. In contrast, industrial minerals are generally produced in low tonnages with moderate to high unit price, can be distant from markets, and require extensive processing. This study, for simplicity, uses the term "industrial minerals" as a collective term for all the industrial rocks and minerals, exclusive of construction aggregate.

Next to construction aggregate resources in Stanislaus County, the kaolinitic claystone and perhaps quartzose sandstone of the Ione Formation in the eastern part of the county probably have the most promise for future economic development. In particular, the sandstones, which have matrixes of kaolinite, could be processed for both specialty sand and kaolinitic clay, as they have been farther north in Ione in Amador County (Glasmann and others, 1989). For these reasons, we intensively studied the Ione Formation to determine its potential for these resources.

Specific work on the Ione Formation included field investigation of numerous exposures and all known mines, and a detailed residual gravity analysis of the Cooperstown-La Grange area. The gravity study (Appendix C) was conducted to attempt to determine if any sort of buried valley cut into the basement was present. Such a feature could be a favorable site for finding thick sequences of Ione claystone and sandstone similar to, but on a smaller scale than, the world-class deposits at Ione in Amador County. We were fortunate to obtain geologic logs from two drilling projects in the Cooperstown area, one conducted in the early 1960s (Plate 11; Padan, 1963) and the other in 1980 (Plate 11; Exxon Coal and Minerals Company, unpublished data). These data were invaluable in interpreting the gravity data and in the evaluation of the mineral potential of the Ione throughout the area. In addition, by use of X-ray diffraction, we determined the mineral composition of a few hundred claystone and sandstone cuttings from many of the drill holes of the earlier drilling project (Churchill and Higgins, in preparation). A note of caution is that the locations of the holes of the earlier project are approximate; they were interpreted from descriptions given to the nearest quarter-quarter section. Also, the apparent thicknesses of the Ione Formation given in the table on Plate 11 assume that there are no older sedimentary horizons between the Ione and the crystalline basement.

Regarding classification, several areas with deposits of industrial minerals were studied sufficiently to classify them as MRZ-2a or MRZ-2b. The deposits consist of kaolinitic clay, specialty sand, diatomite, and quartz (silica). Estimates of tonnages were made to determine if the deposits met the threshold amounts as described in Part II. For the other known industrial minerals (magnesite, expansible shale, dimension stone), records

of past production and/or our knowledge of reserves required that no areas be classified higher than MRZ-3a.

Characteristics of each of the industrial mineral commodities classified in the county are described below.

CLAY

Clay is one of the leading industrial minerals both in terms of tonnage and value (Patterson and Murray, 1983). A variety of industries that are important in local and regional economies use substantial amounts of clay. The term "clay" generally means a natural, earthy, fine-grained material; it commonly is used either in reference to a definite group of hydrous aluminum-silicate minerals, or to indicate detrital rock particles of the smallest grain size, regardless of mineral composition.

Because clays have been utilized for so many purposes over a long period of time and are such a diverse group of materials, many classification systems have been used in their description. Clays may be classified on the basis of their origin, as residual (formed in place) and sedimentary (transported from their place of origin). The terms "high-alumina" clay and "ferruginous" clay refer to chemical properties; "brick" clay and "bleaching" clay refer to use. For statistical information, the U.S. Bureau of Mines employs a classification system based on industrial use, as follows (Kelley, 1966):

kaolin clay
ball clay
fire clay
bentonite
fuller's earth
common clay

In Stanislaus County, the clays mined include ball clay and common clay; some of the ball clay can also be classified as fire clay. Locally, clayey horizons in the Valley Springs Formation have been reported to be "bentonitic" (Bacon, 1963), although this characteristic was not verified in the present study. It is possible that kaolin is also present in the Ione Formation, but none has been reported.

Ball clay is important due to its high plasticity and bonding power. Ball clay is composed largely of kaolinite, sericite micas, and organic matter. It fires to a light color, has high dry strength, and is blended with other clays to enhance their workability in manufacturing ceramic products.

Common clay include mixtures of clay minerals with other minerals, impure varieties of clays, or clay-sized particles of any mineral. For specific purposes, they are blended with higher-quality clays to develop certain properties. Large quantities of common clays go into the manufacture of heavy clay products, such as common brick, tile, and sewer pipe. Common clay is also used as liner material for solid waste dumps.

Fire clay is made up primarily of kaolinite-group minerals, but varies widely in composition. Its most important property is high heat resistance, and it is subdivided into several classes, based on a test known as the pyrometric cone equivalent (PCE). It is defined as any clay that is not white-burning and has a PCE greater than 19 (Patterson and Murray, 1983). Fire clay is used in a variety of ceramic products, from common brick to art pottery, sewer pipe, and ornamental tile.

Bentonite consists mainly of smectite clay minerals, commonly formed by the alteration of tuff or volcanic ash (Patterson and Murray, 1983). It can be either swelling or non-swelling and is commonly used in drilling mud, foundry-sand bonding, and iron-ore pelletizing.

Kaolin clay is composed largely of the mineral kaolinite, but may have much quartz, mica, feldspar, or other minerals present. Because it is white, kaolin is used in whiteware bodies and other high-grade ceramic uses, as a filler, and as coating in papermaking. Some uses of kaolin, such as a filler, require rigid specifications, whereas other uses, such as in cement manufacture, require practically no specifications.

General Characteristics of Clay Deposits in the County

Ball clay has been mined in eastern Stanislaus County in the Ione Formation, exposed between Knights Ferry and La Grange. Because of the deltaic and fluvial origin of the Ione, deposits of clay typically were deposited in shallow basins as lensoidal bodies. Consequently, any lateral continuity between clay horizons over any appreciable distance is difficult or impossible to establish. Color of the clays ranges from very pale gray to chocolate brown on fresh surfaces; parts may have iron oxide staining (red or yellow). Samples from various sites fire to a very light cream or off-white color (Padan, 1963; James Kraft, Kraftile Company, personal communication, 1993). Because of their physical and chemical properties, the Stanislaus ball clays have generally been blended with other materials for various uses, rather than used solely. Advantages include high green and fired strength, light color when fired, and good plasticity, forming characteristics, and drying behavior (Padan, 1963; Wild and Key, 1963). Disadvantages include high silica content and various amounts of organic material (lignite). The pyrometric cone

equivalent measured on about a dozen Stanislaus samples ranged from 18 to 30 (Padan, 1963). The Stanislaus deposits have been used in the past mainly for white sanitary ware, structural building tile, and in pottery.

Common clay was mined locally from Quaternary sediments near towns in the Central Valley. Used for common building brick, none of these deposits has been active for many decades.

Both chemical analyses and a comparison of X-ray diffraction patterns between the Stanislaus clays and representative samples of the Ione Formation from both Ione in Amador County and from Lincoln in Placer County are presented in Appendix B. The geochemical data indicate that the most common mineral assemblage in clay samples collected from the Ione Formation in Stanislaus County is quartz-kaolinite. The next most common is quartz-kaolinite-smectite. The kaolinite is poorly crystallized. Also, the Stanislaus clays have a relatively high percentage of finely-divided quartz compared to the kaolin clays in Amador County. Overall, the Stanislaus clays are more similar to the Lincoln clays than the Amador County clays. The dominant assemblage in the Valley Springs Formation is quartz-kaolinite-smectite-albite, with the smectite more prominent here than in the Ione.

DIATOMITE

Diatomite is a low-density, generally light-colored sedimentary rock composed mostly of very fine-grained siliceous shells of minute plants called diatoms (Oakeshott, 1957). Formed in both oceans and lakes, these deposits may have various amounts of clay and other minerals, which can limit the industrial uses of the diatomite. The properties that most distinguish diatomite as an industrial mineral are its porosity and permeability, which are caused largely by perforations in the shells and loose packing of the particles (Cleveland, 1966). Most diatomite is consumed for its most valuable use, which is for filtration of liquids ranging from beverages to water in swimming pools. Besides its other major use as a filler, diatomite has some 300 different applications.

Diatomite has been mined from the Eocene Kreyenhagen Shale in southwestern Stanislaus County near Crow Hill. This marine formation extends southeastward from here for many miles in the Coast Ranges (Burnett, 1991). Because of the high percentage of clay (Appendix B) in the diatomite, its best uses are probably as filler, insulation, and absorbent; it has been used in the past for all three of these applications. Chemical analyses and brightness measurements are presented in Appendix B. Photographs of the diatomite, taken with a scanning electron microscope, are presented in Appendix D.

MAGNESITE

Magnesite ($MgCO_3$) forms by replacement of dolomite, by hydrothermal replacement or fracture-filling in serpentinite, or by evaporation in saline lakes to produce sedimentary deposits (Ver Planck, 1957; Smith, 1966). Generally, the deposits formed in serpentinite are small and comparatively pure, whereas those formed in the other two environments are impure. In the first half of this century, magnesite was a major source of the magnesia (MgO) used in refractories. Since then, in California, it has been replaced by use of a process that combines both sea water and dolomite. High-purity magnesite still has specialized uses in the chemical industry, however.

Magnesite has been mined at two main localities in southwestern Stanislaus County, one on the flanks of Red Mountain and the other along Quinto Creek, southwest of Newman. Both areas consist of replacement and fissure-filling deposits in serpentinized ultramafic rock. Although relatively small compared to major world sources, these deposits are noted for their high purity; chemical analyses are presented in Appendix B.

QUARTZ (silica)

Quartz (SiO_2) is one of the most common minerals in the Earth's crust, yet, as a source of industrial silica, it is limited to particular geologic occurrences. In California, these occurrences include the metamorphic rock quartzite, vein quartz, quartz-rich gravels, and pegmatite (Clark and Carlson, 1957). Excluded from this category are the quartz-rich specialty sands described in the section below. Main uses of quartz as industrial silica include production of ferrosilicon and portland cement, manufacture of silica firebricks, and applications in the aluminum and chemical industries. Deposits of quartz should be of high purity, easily mined, and near transportation facilities (Ross, 1966).

Of the four geologic occurrences of quartz as a source of industrial silica listed above, only vein quartz has any potential in Stanislaus County. Vein quartz of large extent is rare in the Coast Ranges and very limited in the crystalline basement complex of the Sierra Nevada foothills. It has been mined at one locality, which is in the Coast Ranges along Del Puerto Canyon. Quartzite and pegmatite are not known nor expected to be present. Quartz-rich gravels are present locally in the Ione Formation, but these are of limited extent and are commonly strongly indurated by silica cement.

SPECIALTY SAND

Specialty sands are those used for purposes other than aggregate, ballast, or fill (Goldman, 1966a). They generally have rigid physical and chemical specifications, and are used in much smaller quantities than regular construction sand (Gay, 1957). The most common uses for specialty sand include sandblasting and other abrasives, foundry (molding) applications, and manufacture of plate and container glass. For sandblasting, hardness and durability are important. Foundry sands must be able to withstand high heat, be non-reactive, and have sufficient cohesiveness to hold together when wet. Bonding material (such as 5 to 10 percent clay) can naturally occur with the sand or be added. Such sands are used to make kiln brick or molds for the steel, electrical and ceramic industries. Glassmaking requires sand with rigorous chemical qualities. Paramount is a high silica content and low iron content, although certain container-glass sand can have as much as 50 percent feldspar (Gay, 1957). Traces of other elements and minerals may also be undesirable.

Specialty sand is not known to have been mined in Stanislaus County, although the Ione Formation, Poverty Flat Sandstone, and Tesla Formation all have strata that are potential sources. To the north, in the Ione area of Amador County, the Ione Formation has been mined extensively for glass sand (Pask and Turner, 1952). To the northwest, in the Tesla area of Alameda County, the Tesla Formation has been mined for both glass and foundry sand (Huey, 1948). The Poverty Flat Sandstone is known to be exposed only in Stanislaus County (Bartow, 1984). The sandstone of all three formations is characterized by high percentages of angular quartz in a matrix of white kaolinitic clay, probably derived mainly from in-place weathering of feldspar; variable amounts of iron locally impart a yellow or red color to the rock. The Tesla Formation may have higher amounts of feldspar than the other two formations.

Of particular note is the fluvial origin of the sandstone of the Ione Formation, which is described in detail by Rodgers (1986). This environment resulted in a braided pattern of sandstone deposition, which makes establishment of lateral continuity between observed horizons difficult or impossible. The braided character of the deposits is also apparent from electric logs obtained during the Exxon drilling project in the Cooperstown-La Grange area (Plate 11).

Many samples of sandstone were analyzed for mineral assemblages by X-ray diffraction and several were analyzed for major-oxide chemistry by whole-rock techniques (Appendix B). For the Ione Formation, most samples had the assemblage quartz-kaolinite. The next most abundant assemblage was quartz-kaolinite-potassium feldspar. Smectite was a minor constituent in only a few samples. Across the Great Valley, the Poverty Flat

Sandstone showed mineral assemblages very similar to the Ione. The Tesla Formation appears in general to have an assemblage of quartz-kaolinite-feldspar. A comparison of X-ray diffraction patterns between samples from the Ione and Poverty Flat are presented in Appendix B.

EXPANSIBLE SHALE

Expansible shale is any fine-grained, clay-rich sedimentary rock that expands when rapidly heated in a high-temperature kiln (Rogers and Chesterman, 1957; Burnett and Weiler, 1966). Such processing produces a light-weight material that is used as concrete aggregate for buildings. Although expansible shale is technically a "construction aggregate," in this report we have placed it in the industrial minerals category because the raw material requires extensive processing.

Expansible shale is not known to have been mined in Stanislaus County. It has been mined in the San Francisco Bay Area from the Great Valley Sequence and the Franciscan Complex, two units that are extensively exposed in the county.

DIMENSION STONE

Dimension stone is natural stone that can be cut or broken into definite shapes or sizes (Goldman, 1966b). The principal uses of dimension stone are in building construction and monuments (Power, 1983). Other uses include curbstones and paving blocks. Stone must be free of fractures and iron-bearing sulfides, have consistent texture and grain size, and be of attractive color (Goldman, 1957). Around 1900, dimension stone accounted for more than half the stone produced in the United States, but by 1981 it accounted for only about 0.1 percent (Power, 1983). Over this period, competition from cheaper synthetic materials, demand for uniform products, foreign imports, and high costs of domestic labor have been the main causes of this decline. Nonetheless, dimension stone is a high-value mineral commodity, and the building industry is returning to its use as an aesthetic alternative to the blandness of synthetic materials.

Dimension stone has been mined in eastern Stanislaus County from both the Ione Formation and the Merced Falls Slate. From Knights Ferry to La Grange and vicinity, the Ione Formation has horizons of well-indurated sandstone that display visually attractive shades of red, pink, and yellow. In the La Grange area, the Merced Falls Slate has widely distributed exposures of dark gray slate with moderate to steeply dipping cleavage. In the Coast Ranges, well-indurated sandstone of the Great Valley Sequence has potential as dimension stone. Although not mined in

Stanislaus County, such rock was mined from equivalent formations farther north at the Sites area in Colusa County; this locality was the principal source of dimension sandstone in California (Goldman, 1957).

HYDROTHERMAL PROCESSES (precious metals and mercury)

Ore deposits formed by hydrothermal processes represent a major source of metallic mineral resources and, to a lesser extent, non-metallic minerals. The metals formed include gold, silver, copper, lead, zinc, mercury, antimony, tin, tungsten, molybdenum, vanadium and minor elements. The more common non-metallic deposits include barite, zeolite, and various types of clay.

Hydrothermal ore deposits are formed from metal-enriched fluids that may originate in a cooling magma body or may be from connate or meteoric waters, which are heated by a magma body. Convection causes the fluids to move away from the heat source via fractures, faults, fault zones, porous rock or other open cavities in host rocks. During movement, the fluids undergo chemical changes by reaction with the host rocks and also experience physical changes by both cooling and lowering of pressure. These combined effects cause the minerals in the fluids to precipitate in the faults, fractures, and pores, or to chemically replace favorable rock. If pervasive, the replacement process is termed "hydrothermal alteration," which may include substantial introduction of such materials as silica (silicification), clay (argillization), or iron (hematite and limonite). Zones of alteration may have no value as resources, but may be used as an aid in finding hydrothermal ore deposits. For this study, this class of mineral deposits excludes those formed in submarine volcanic environments by hydrothermal processes.

Metals known or suspected to be associated with this class of mineral deposit in Stanislaus County include mercury, gold, and silver. Mercury is presently used mainly in electrical and electronic applications and in the chemical industry. Gold, besides its monetary use, is used mostly for jewelry, with lesser use for electronics and dentistry. Silver, besides its monetary use, is mainly used in the photographic industry, with lesser use in jewelry and electronics.

Known and potential hydrothermal deposits in the county can be classified into two broad epigenetic groups. In the east, one group is associated with the Sierran Foothills Terrane and was formed under mesothermal (moderate temperatures and pressures) conditions. Expected metals of importance are gold and silver. In the west, the other group is associated with the Coast Ranges and was formed under epithermal (low temperatures and pressures)

conditions. Expected metals of importance are mercury and possibly gold. Each group was formed under distinctly different conditions in time and space.

Regarding the mesothermal group, the absence of known mineralization in the county requires that no area can be classified higher than MRZ-3b. In the Coast Ranges, the small production and the lack of knowledge on reserves at known epithermal deposits require that no area can be classified higher than MRZ-3a.

MAGMATIC SEGREGATION (chromite)

Magmatic segregation is a process in which a particular mineral or group of minerals concentrates in certain parts of a magma chamber during its cooling and crystallization. Commonly, such segregations are found in ultramafic rocks and mafic plutonic rocks (high in iron and magnesium).

Chromite ($FeCr_2O_4$), which is found in the variably serpentinized ophiolitic ultramafic rocks of southwestern Stanislaus County, is one of the best examples of a mineral commodity formed by magmatic segregation. It is the world's only economic source of chromium, an extremely strong metal that is resistant to chemical attack, abrasion, corrosion, and high temperatures (Mikami, 1983). Chromite is used for stainless steel, as a refractory material, and in the metallurgical and chemical industries. Because there are no active chromite mines in the United States, this commodity is considered a strategic material.

As is typical world-wide, the chromite deposits of the county are present in both massive and disseminated form. The specific host rock is almost exclusively dunite, an ultramafic rock composed largely of the mineral olivine. Commonly, the massive ore bodies are aligned along shear zones in the host rock, which suggests that the bodies served as favorable sites of later shearing (Rice, 1957; Evarts, 1978).

Study of aeromagnetic data (Appendix C) was useful in finding the extent of serpentinized ultramafic rock in the Coast Ranges. Some of these bodies were either not mapped by previous workers or are much more extensive in the subsurface then indicated by surface exposure. Specifically, the aeromagnetic data were used to expand the Mineral Resource Zones that represent areas with favorable geologic environments for the presence of chromite deposits.

Although there are many deposits of chromite in the ultramafic rocks of the county, past production and the meager

knowledge of reserves of these deposits require that no area in the county can be classified higher than MRZ-3a.

VOLCANOGENIC PROCESSES (base and precious metals)

Ore deposits formed by volcanogenic processes are defined here as those formed on or near the sea floor by discharge of metal-bearing hydrothermal fluids from submarine thermal springs. Typically, the heat sources for the fluids are underlying magma chambers, which also feed volcanic conduits. The most common environments of such systems are sea-floor spreading centers and island arcs.

Metals known or suspected to be associated with this class of mineral deposits in Stanislaus County include base metals (copper, lead, zinc), gold, and silver. Copper is used mostly in building construction and in electrical and electronic products. Lead is used in many products; most is consumed by those related to transportation such as batteries and fuel tanks. Similar to lead, zinc has many uses, the majority of which involve galvanizing.

Volcanogenic deposits with the above metals have not been mined in Stanislaus County, but have been extensively mined just across the county line in both Calaveras County and Tuolumne County (Plate 8C; Clark and Lydon, 1962; Heyl, 1948b; Logan, 1949; Taliaferro and Solari, 1949). This area is part of a larger region of mineralization in the Sierra Nevada known as the Foothill Copper-Zinc Belt (Heyl, 1948a; Martin, 1988). This belt extends for about 300 kilometers in a northwesterly direction and is associated with the island-arc metavolcanic rocks of the Foothills Terrane. In particular, both base and precious metals are found in massive sulfide bodies emplaced within felsic, calc-alkalic rocks of the Gopher Ridge Volcanics (Kemp, 1982). The origin of the deposits is in some dispute. Heyl (1948a) believed they were epigenetic, formed after the Nevadan Orogeny and its associated metamorphism. More recently, several workers (Kemp, 1982; Albers, 1981; Martin, 1988; Peterson, 1985) have reinterpreted the deposits as largely syngenetic features that were subsequently modified and remobilized to some extent by metamorphism during the Nevadan Orogeny. Kemp (1982) specifically has classified them as analogous to the Kuroko or Noranda types.

Aeromagnetic data (Appendix C) were used in the eastern part of the county and adjacent counties to determine if there is a correlation between anomalies and the locations of known base-metal deposits. Although not conclusive, there is a weak correlation between positive anomalies and known deposits in Tuolumne and Calaveras Counties. This information assisted in defining the Mineral Resource Zone, described in Part IV, that

represents areas with favorable geologic environments for the presence of base-metal deposits.

Although there are local zones of base-metal mineralization in the exposed areas of the Gopher Ridge Volcanics, we did not study any of these in enough detail to determine if they are significant deposits. Consequently, no area is classified higher than MRZ-3a.

VOLCANOGENIC-SEDIMENTARY PROCESSES (manganese)

The genesis of a particular group of manganese deposits that are situated in the California Coast Ranges, including Stanislaus County, is controversial. Two very different models have been proposed for their origin; consequently, we have put them in a category that is a combination of two classes of mineral deposits, volcanogenic and sedimentary, to reflect this disagreement. Both of these classes are the two primary categories used by Roy (1992) in a scheme to classify the processes of manganese deposition.

The volcanogenic model for the Coast Range manganese deposits is similar to that described in the previous section on base-metal mineralization in the Sierra Nevada. First suggested by Taliaferro and Hudson (1943), it has been expanded upon and recast in the light of plate tectonics by Snyder (1978), Crerar and others (1982), and Huebner and Flohr (1990). In this model, the deposits of the Coast Ranges were formed by submarine hydrothermal processes active in rocks that would later be accreted to the North American continent as the Franciscan Complex.

In contrast, the second model interprets the deposits to have formed by a combination of sedimentation and diagenetic replacement, assisted by methane-producing bacteria (Hein and others, 1987; Hein and Koski, 1987). In this model, the manganese was initially deposited from the water column as sediment within the associated rhythmic chert-shale sequences. Subsequently, during diagenesis, bacteria in the sediment column produced methane, which was oxidized in the overlying sediments to CO_2. This compound then combined with the manganese in the chert-shale sequences to produce rhodochrosite, recognized by workers as the primary ore mineral of the deposits.

Manganese has been mined from many properties in the Franciscan Complex of southwestern Stanislaus County. The deposits are characterized by high-grade but small size. Primary mineralization consists mainly of rhodochrosite and manganese silicates (Trask and others, 1950). At and near the ground surface, supergene processes have enriched these deposits by conversion to manganese oxides. They are interbedded with chert

horizons that are generally associated with graywacke and/or greenstone. Typically, the manganese horizons are in conformable contact with massive chert rather than the more extensive thin-bedded chert. Deposits are lenticular in shape (likened to pancakes by Trask and others, 1950) and are no more than hundreds of feet in lateral dimension or tens of feet thick. Because of this restricted depositional geometry and the structural disruption of the Franciscan in general, the manganese deposits are difficult to follow in the subsurface and even more difficult to discover.

The main use of manganese is in steelmaking; substantially lesser amounts are used in dry cell batteries and other applications. As with chromite, manganese is classed as a strategic material because it is not mined in the United States.

Although there are numerous deposits of manganese in the southwestern part of the county, past production, the generally small size of individual deposits, and the meager knowledge of reserves require that no area be classified higher than MRZ-3a.

PART IV

SPECIFIC DESCRIPTIONS OF AREAS CLASSIFIED IN STANISLAUS COUNTY

PART IV - SPECIFIC DESCRIPTIONS OF AREAS CLASSIFIED IN STANISLAUS COUNTY

Presented in this section are specific descriptions of the individual areas classified on the accompanying Mineral Land Classification Maps as listed below:

Construction Aggregate	Plates 2A, 2B, 2C
Industrial Minerals	Plates 4A, 4B
Hydrothermal	Plates 6, 7
Magmatic Segregation	Plate 5
Volcanogenic	Plate 7
Volcanogenic-Sedimentary	Plate 5

Each Mineral Land Classification Map shows Mineral Resource Zones for one or more of the classes of mineral deposits listed in Table 2. Each zone on the map is further discriminated by superscripts that denote the class of mineral deposit and either the type of commodity (metallic and industrial) or the use of the commodity (construction aggregate). Those superscripts with numbers refer to unique areas that are specifically described in the text. Those without numbers refer to areas described in a general way in the text. The sequence of numbering is generally from west to east and north to south. A few examples of the notation used for Mineral Resource Zones are presented in Figures 8a, 8b, and 8c.

Within a given category of areas classified, the descriptions proceed sequentially in order from MRZ-1 through MRZ-2, MRZ-3, and MRZ-4. The Map Number (shown on Plates 8A, 8B, or 8C and listed in Appendix A) of mines and prospects described in this section are given in parentheses following the first mention of the mine or prospect. Each area is also identified by a prominent geographic feature.

AREAS CLASSIFIED FOR CONSTRUCTION AGGREGATE

CONSTRUCTION AGGREGATE IN GENERAL

Areas Classified MRZ-1

MRZ-1 - Western and Eastern County (Plates 2A and 2C): Areas classified as MRZ-1 on Plates 2A and 2C were judged--on the basis of available data--to have little likelihood of containing significant deposits of concrete-grade aggregate. Geologic units that have excessive amounts of deleterious silt, clay, organic matter, absorptive or alkali-reactive rock, platy or soft rock

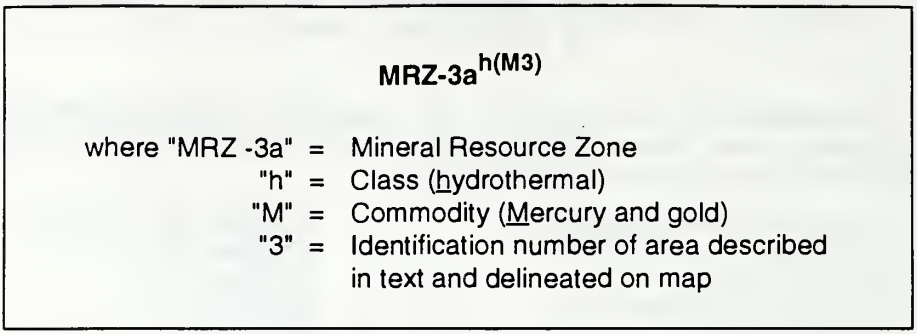

MRZ-3a h(M3)
where "MRZ -3a" = Mineral Resource Zone
"h" = Class (hydrothermal)
"M" = Commodity (Mercury and gold)
"3" = Identification number of area described in text and delineated on map

FIGURE 8a. – Example of notation used for mineral resource zones related to metallic minerals.

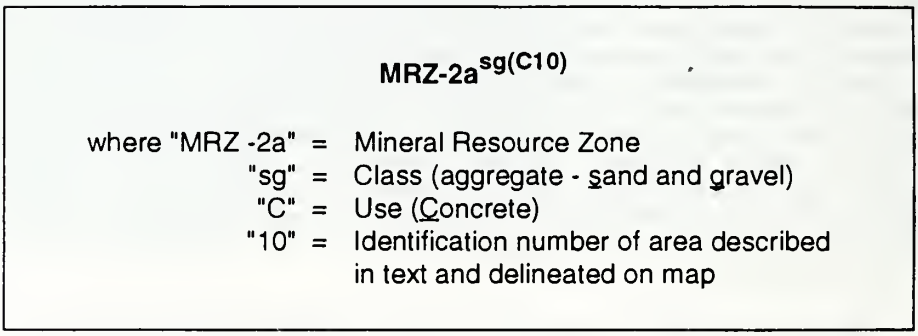

MRZ-2a sg(C10)
where "MRZ -2a" = Mineral Resource Zone
"sg" = Class (aggregate - sand and gravel)
"C" = Use (Concrete)
"10" = Identification number of area described in text and delineated on map

FIGURE 8b. – Example of notation used for mineral resource zones related to construction aggregate.

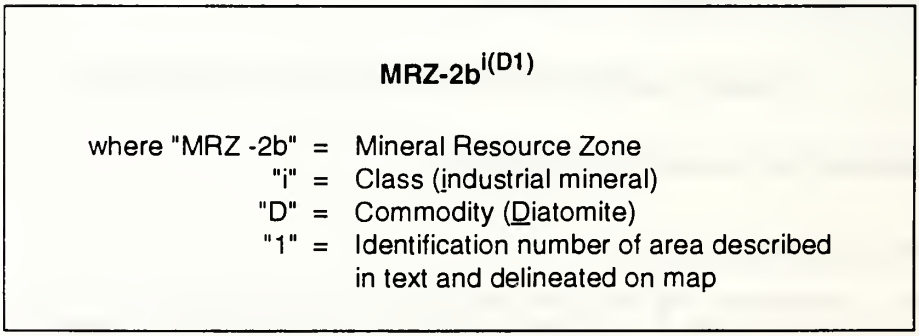

MRZ-2b i(D1)
where "MRZ -2b" = Mineral Resource Zone
"i" = Class (industrial mineral)
"D" = Commodity (Diatomite)
"1" = Identification number of area described in text and delineated on map

FIGURE 8c. – Example of notation used for mineral resource zones related to industrial minerals.

are unsuited for use in concrete aggregate. Areas containing such deposits are classified MRZ-1 on Plates 2A and 2C.

Areas Classified MRZ-4

MRZ-4 - Western and Eastern County (Plates 2A and 2C): Areas classified as MRZ-4 include geologic units for which available information on concrete-grade aggregate is lacking or incomplete for assignment into the other MRZ categories. Two regions within Stanislaus County include MRZ-4 zones; one region includes the western-most portion of the county on Plate 2A, the other region includes scattered areas in eastern Stanislaus County on Plate 2C.

MRZ-4 areas on Plate 2A include rocks of the Franciscan Complex and the Coast Range Ophiolite that occur in the western-most portions of Stanislaus County within the Coast Ranges. Franciscan Complex rock units include a fragmented, highly faulted, sheared, jointed, disorganized and intermixed assemblage of highly altered marine sedimentary and volcanic bodies. Similarly, the Coast Range Ophiolite includes thick sequences of metamorphosed and highly altered marine mafic and ultramafic igneous rocks. Individual rock bodies in both the Franciscan Complex and the Coast Range Ophiolite are difficult to identify or map, and vary widely in hardness, durability, alteration, and texture.

MRZ-4 areas on Plate 2C include rocks of the regionally extensive Mehrten Formation. This unit is characterized by massive tonnages of andesitic volcanic debris and ranges in age from 4-16 million years. Rock textures within this unit are inconsistent and range from poorly consolidated alluvial sands and gravels to highly consolidated and cemented brecciated lahars. Andesitic clasts within the Mehrten Formation range from 60 percent to over 95 percent by volume. Opalized-silica coatings on cobbles within the Mehrten Formation are locally common. This unit weathers easily and forms "haystack hills" that are common throughout eastern Stanislaus County. Roadcuts and outcrops within the Mehrten Formation demonstrate that up to 12-foot lenses of weathered, poorly-consolidated and friable conglomerate occur within this unit. Typically, the abundant andesitic pebbles and cobbles within these conglomerate units are highly weathered and have well-developed weathered rinds on the surfaces. Modern processing technology is currently employed by R.C. Collet, Inc. to economically mine and process Mehrten Formation material at its Rocklin Pit in Placer County for use as AC aggregate. Although much of the Mehrten Formation is unsuited for use as concrete-grade aggregate, this formation may contain more favorable concrete-grade alluvial conglomerate strata or lahar channels at depth.

SAND AND GRAVEL (concrete aggregate)

Areas classified for sand and gravel resources in Stanislaus County are shown on Plates 2A, 2B, and 2C. The classified areas are identified by the following superscript: $^{sg(C)}$ indicating "sand and gravel-(Concrete grade)." Superscript reference numbers are used to identify specific MRZ-2a, MRZ-2b, and MRZ-3a deposits discussed in this section. For example, MRZ-2b$^{sg(C2)}$ specifically identifies the Orestimba Creek Fan area. Deposits of a given classification type are numbered from west to east and from north to south across each Plate. All of the aggregate currently being mined within Stanislaus County is obtained from alluvial deposits; there have been no crushed rock quarry operations for aggregate in Stanislaus County within the past 20 years.

Lands within six geographic areas in this study are classified MRZ-2a$^{sg(C)}$ and/or MRZ-2b$^{sg(C)}$ for concrete-grade aggregate. These are areas for which available data indicate that either proven concrete-grade aggregate exists (MRZ-2a$^{sg(C)}$) or there is a high likelihood that significant deposits of concrete-grade aggregate exist (MRZ-2b$^{sg(C)}$). All of these areas contain unconsolidated Pliocene or younger alluvial sand and gravel deposits. The six geographic areas are:

(1) Hospital Creek Fan (Plate 2A),
(2) Orestimba Creek Fan (Plate 2A),
(3) Garzas Creek Fan (Plate 2A),
(4) Calaveras River Elevated Terrace in northeastern Stanislaus County (Plate 2C),
(5) Stanislaus River (Plate 2C), and
(6) Tuolumne River (Plate 2C).

Generally, the sedimentary deposits that form the Hospital Creek Fan, Orestimba Creek Fan, and Garzas Creek Fan MRZ-2a$^{sg(C)}$ and MRZ-2b$^{sg(C)}$ areas occur as inset channels, low-relief mantled pediment, and nested terrace surfaces that overlap regionally extensive alluvial fan deposits along the eastern foothills of the Coast Ranges.

The sedimentary deposits that form the MRZ-2a$^{sg(C)}$ and MRZ-2b$^{sg(C)}$ areas in the eastern portion of Stanislaus County were created by the Calaveras, Stanislaus, and Tuolumne Rivers, and occur as elevated and/or nested river channel terraces.

Areas Classified MRZ-2a$^{sg(C)}$

MRZ-2a$^{sg(C1)}$ - Hospital Creek Fan, Vernalis Site (Plate 2A): Granite Construction Company is currently requesting a permit to mine this site for concrete-grade aggregate. The northwestern third of this 0.5 square-mile area was previously classified as MRZ-2 for concrete-grade aggregate by the Division of Mines and

Geology (Jensen and Silva, 1988, Plate 17), and designated as a portion of Sector C-9 by the State Mining and Geology Board (California Department of Conservation, 1990, Designation Map No. 89-1R). Moreover, the southeastern two-thirds of this area was previously classified as MRZ-3 for concrete-grade aggregate (Jensen and Silva, 1988, Plate 17). The MRZ-3 area determined in that study is reclassified in this report because additional proprietary aggregate engineering test data was provided by Granite Construction Company that demonstrates significant amounts of concrete-grade aggregate occurs at this site. The aggregate at this site is poorly sorted Holocene and Pleistocene alluvium. Pebbles and coarser-sized clasts are generally composed of undifferentiated metasedimentary rocks, metagraywacke, quartzite, vein quartz, metachert, and lesser amounts of sandstone and claystone.

MRZ-2a$^{sg(C2)}$ - Orestimba Creek Fan, Stuhr Road Quarry (Plate 2A): Frank B. Marks and Sons, Inc. is currently mining concrete-grade sand and gravel in this 0.28 square-mile area. This site and nearby areas within the Orestimba Creek channel have been mined for concrete-grade aggregate since 1906. The mined material contains about 35-45 percent sand and finer-sized silt and clay and 55-65 percent gravel and coarser-sized clasts. Pebbles and coarser-sized clasts are subrounded to subangular and chiefly composed of sandstone, vein quartz, metagraywacke, metachert and lesser amounts of schist, metavolcanic rocks, siltstone and serpentine.

MRZ-2a$^{sg(C3)}$ - Calaveras River, Elevated Terrace Site (Plate 2C): Granite Construction Company is currently requesting a permit to mine this 0.89 square-mile site for concrete-grade aggregate. This area was previously classified as MRZ-3 for concrete-grade aggregate by the Division of Mines and Geology (Jensen and Silva, 1988, Plate 8). It is upgraded from an MRZ-3 in that report and reclassified as MRZ-2a$^{sg(C3)}$ for concrete-grade aggregate in this report because additional proprietary aggregate engineering test data was provided by Granite Construction Company that demonstrates concrete-grade aggregate occurs within this site. Much of the northern third of this site was dredged for gold during the 1930s; however, the dredged material is composed of the same rock composition as is that throughout the rest of this site. Pebbles and larger-sized clasts are principally composed of rounded to subangular greenstone, vein quartz, undifferentiated metasedimentary rocks, quartzite and lesser amounts of granitic rocks and volcanic rocks. The aggregate at this site is composed of Pliocene Laguna Formation alluvium.

MRZ-2a$^{sg(C4)}$ - Stanislaus River, Riverbank Area (Plate 2C): George Reed, Inc. has been mining concrete-grade aggregate in the southern half of this site since 1991. The mined material is trucked to the Munn and Perkins plant near Escalon and processed for use as AC and road base. The northern half of this 0.30

square-mile area was dredged for gold in the 1930s. Thicknesses of the dredge tailings generally vary from 25-40 feet. Alluvium lithology is the same in both the northern and southern halves of this area. The sand and gravel is composed of Pleistocene Modesto Formation and occurs within an elevated terrace of the ancestral Stanislaus River. Sand and finer-sized clasts generally make up about 70 percent of this deposit. Gravel and more coarse-grained material is predominately composed of rounded to subangular granitic rocks, undifferentiated metasedimentary and metamorphic rocks, greenstone, vein quartz, with lesser amounts of andesite and more basic volcanic rocks. Maximum clast size is 7 inches.

MRZ-2a$^{sg(C5)}$ - Tuolumne River, Hatch Road Area (Plate 2C): Concrete-grade sand and gravel has been mined from this 0.88 square-mile site since 1946. Western Stone Products, Inc. is currently mining aggregate at its Hickman Pit in the eastern quarter of this site. Proprietary aggregate engineering test data proves that the western three-fourths of this site contains concrete-grade material. Mined material from the Hickman Pit is used in PCC, AC and road base. The sand-sized fraction is arkosic and chiefly composed of quartz, biotite, and feldspar. The mined material is composed of Holocene and Modesto Formation alluvium and occurs in an elevated Tuolumne River terrace. Gravel and coarser-sized clasts are predominately composed of well-rounded to rounded siliceous undifferentiated metasedimentary and metamorphic rocks, quartzite, vein quartz, greenstone, and granitic rocks, with lesser amounts of volcanic rocks, diorite, and claystone. Clay lenses and cross-bedded coarse-grained sand lenses (3-7 feet thick) are common throughout the deposit. Maximum clast size is about 6 inches.

MRZ-2a$^{sg(C6)}$ - Tuolumne River, Waterford Area (Plate 2C): Concrete-grade aggregate has been mined at various sites in this 1.92 square-mile area since the 1950s. George Reed, Inc. mined the westernmost portion of this site in the 1970s and is currently permitted to mine aggregate at its Waterford Site (which includes this previously mined area). M.J. Ruddy & Son, Inc. is currently mining concrete-grade aggregate at its Waterford Pit in the central portion of this area. Another company, 7/11 Materials, Inc., is currently mining concrete-grade aggregate at its Waterford Pit, which covers the eastern portion of this area. The mined material is Holocene and Modesto Formation alluvium and occurs in an elevated Tuolumne River terrace. Clast sizes generally consist of 60-70 percent sand and finer-sized material. Gravel and coarser-sized clasts are primarily composed of well-rounded to subrounded siliceous undifferentiated metasedimentary and metamorphic rocks, quartzite, vein quartz, greenstone, and granitic rocks, with lesser amounts of volcanic rocks, diorite, and claystone. Clay lenses and cross-bedded coarse-grained sand lenses (3-7 feet thick) are common throughout this deposit. Maximum clast size is about 8 inches.

MRZ-2a$^{sg(C7)}$ - Tuolumne River, Roberts Ferry Area (Plate 2C): Much of this 1.05 square-mile area was dredged for gold in the 1930s and 1940s. The dredge tailings generally range from 40-60 feet in depth and rise 16 feet or more above the surrounding terrain. The dredge tailings and undredged material at this site have been mined for concrete-grade aggregate since the 1960s. 7/11 Materials, Inc. is currently mining aggregate at its Roberts Ferry Pit in the western third of this area. M.J. Ruddy & Son, Inc. is currently mining aggregate at its La Grange Pit in the central portion of this area, and Western Stone Products, Inc. is currently mining aggregate at its Cree Ranch Pit at the eastern end of this area. The aggregate currently being mined is used in PCC and AC. The mined material is composed of Holocene and Modesto Formation alluvium and occurs within elevated Tuolumne River terraces. Some of the older, more iron-stained dredged material is probably composed of Riverbank Formation alluvium. Gravel and coarser-sized clasts are primarily composed of rounded to subrounded siliceous undifferentiated metasedimentary and metamorphic rocks, quartzite, vein quartz, greenstone, and granitic rocks, with lesser amounts of volcanic rocks, diorite, and claystone. Clay lenses and cross-bedded coarse-grained sand lenses (3-7 feet thick) are common throughout the deposit. The maximum clast size is about 12 inches.

Areas Classified MRZ-2b$^{sg(C)}$

MRZ-2b$^{sg(C1)}$ - Hospital Creek Fan (Plate 2A): Hospital Creek Fan is currently being mined for concrete-grade aggregate at Brown Sand, Inc.'s Vernalis Pit located about a mile to the west of this classified area. During the 1960s the California Department of Transportation excavated extensive amounts of aggregate from Hospital Creek Fan about two-thirds of a mile to the west of this site. The aggregate was used in the construction of Interstate 5. The northwestern fifth of this 1.05 square-mile area was previously classified as MRZ-2 for concrete-grade aggregate by the Division of Mines and Geology (Jensen, 1988, Plate 17) and designated as a portion of Sector C-9 by the State Mining and Geology Board (California Department of Conservation, 1990, Designation Map No. 89-1R). The southeastern two-thirds of this area was also previously classified as MRZ-3 for concrete-grade aggregate (Jensen and Silva, 1988, Plate 17). The MRZ-3 area determined in that study is reclassified in this report because additional aggregate engineering data was obtained that demonstrates concrete-grade aggregate occurs within this MRZ-2b$^{sg(C1)}$ area.

This site is composed of poorly sorted and interbedded Holocene and Pleistocene alluvium, and contains varying proportions of silt, clay, sand, pebbles, cobbles and oversized boulders. Generally, this deposit contains about 50 percent fine sand, silt, and clay. Thick (4 feet or more) clay lenses occur at

depth. The upper 40 feet or so generally contains less clay and friable clasts than do deeper, and older, portions of this fan. The coarser-sized fraction contains well-rounded to sub-rounded clasts up to 8 inches in diameter. Pebbles and coarser-sized clasts are chiefly composed of metagraywacke, metachert, and vein quartz with lesser percentages of quartzite, schist, sandstone, metabasalt and andesite.

MRZ-2b$^{sg(C2)}$ - Orestimba Creek Fan (Plate 2A): The Marks family began mining concrete-grade aggregate from this area in the early 1900s and has continuously mined sand and gravel for PCC and AC from this area since 1924. In 1980 Frank B. Marks & Son, Inc. started scalping sand and gravel from the western portion of this area to the west of the California Aqueduct. Mined material from this fan is composed of Holocene channel and floodplain alluvium. At 30 feet and deeper the sand and gravel may be composed of older Pleistocene alluvium. The maximum known depth of this deposit is about 100 feet near the Marks plant. Aggregate thickness in this deposit tapers off at the eastern portion to depths of only 3-5 feet. The western-most portions of this area predominantly contains sand and smaller-sized clasts at the surface. However, there is a possibility that much coarser material may occur at depth. The mined material is chiefly composed of 65 percent sand and finer-sized clasts. Gravel and coarser-sized clasts are predominately metagraywacke, indurated and cemented sandstone and siltstone, metachert, undifferentiated metamorphic rocks, and lesser amounts of schist, serpentine and metavolcanic rocks.

MRZ-2b$^{sg(C3)}$ - Garzas Creek Fan (Plate 2A): The Merced County Department of Roads has been mining concrete-grade aggregate from this site since 1982. The aggregate is used as AC and road base material. The mined material is composed of Holocene channel and floodplain alluvium. Maximum clast size is about 8 inches. About 50 percent of this material is sand-sized and finer. Gravel and coarser-sized clasts are predominantly composed of metagraywacke, undifferentiated metasedimentary rocks, metachert, vein quartz, quartzite, and lesser amounts of metavolcanic rocks.

MRZ-2b$^{sg(C4)}$ - Calaveras River, Elevated Terrace (Plate 2C): The northern two thirds of this area was previously classified as MRZ-3 for concrete-grade aggregate by the Division of Mines and Geology (Jensen and Silva, 1988, Plate 8). It is upgraded from the MRZ-3 classification in that report and reclassified as MRZ-2b for concrete-grade aggregate in this report because additional proprietary aggregate engineering test data was provided by Granite Construction Company that demonstrates significant amounts of concrete-grade aggregate occurs at this site. The northern third of this site was dredged for gold in the 1930s. Pebbles and larger-sized clasts are principally composed of rounded to subangular greenstone, vein quartz, undifferentiated metasedimentary rocks, quartzite and lesser amounts of granitic

rocks and volcanic rocks. Aggregate at this site is composed of the Pliocene Laguna Formation alluvium. Iron staining is common.

MRZ-2b$^{sg(C5)}$ - Stanislaus River (Plate 2C): Concrete-grade sand and gravel have been mined throughout this 12.49 square-mile area since the early 1900s; concrete-grade aggregate is currently being mined at five sites within this area. Although many portions of this area have been extensively mined in the past, especially within and immediately adjacent to the active Stanislaus River channel, there are notable remaining concrete-grade aggregate deposits within broad elevated terraces in areas away from the active channel. The remaining aggregate resources principally occur within these elevated terraces and are composed of Holocene and Pleistocene Modesto Formation alluvium. Older Pleistocene Riverbank Formation alluvium may be present at depths of more than 25 feet. Sand and finer-sized clasts generally make up about 60-70 percent of these deposits, while gravel and coarse-sized clasts make up about 30-40 percent. Generally, there is a higher percentage of sand and finer-sized clasts (70-80 percent) at the western end of this area. The coarser-sized material is predominately composed of rounded to subangular granitic rocks, undifferentiated metasedimentary and metamorphic rocks, greenstone, vein quartz, with lesser amounts of andesite and more mafic volcanic rocks (Goldman, 1964). Higher percentages of andesitic clasts occur at the eastern end of this area. The maximum clast size near Knights Ferry at the eastern end of this area is about 12-15 inches. In contrast, the maximum clast size near George Reed, Inc.'s Munn & Perkins Pit at the western end of this area is about 5 inches.

MRZ-2b$^{sg(C6)}$ - Tuolumne River (Plate 2C): Concrete-grade aggregate has been mined from this 6.60 square-mile area since the early 1900s. Concrete-grade aggregate is currently being mined at 13 sites within this area. Although many portions of this area have been extensively mined in the past, especially within and immediately adjacent to the Tuolumne River channel, there are notable remaining concrete-grade alluvial aggregate deposits within extensive elevated terraces. These remaining aggregate resources are composed of Holocene and Pleistocene Modesto Formation alluvium. The material generally consists of 60-70 percent sand and finer-sized silt and clay. Gravel and coarser-sized clasts are primarily composed of well-rounded to subrounded siliceous undifferentiated metasedimentary and metamorphic rocks, quartzite, vein quartz, slate, greenstone, and granitic rocks, with lesser amounts of volcanic rocks, diorite, and claystone (Goldman, 1964). Clay lenses and cross-bedded coarse-grained sand lenses (3-7 feet thick) are common at depth throughout the remaining deposits. The maximum clast size is about 12 inches near La Grange at the eastern end of this area. In contrast, the maximum clast size is about 7 inches at the western end of this area near Geer Road.

Areas Classified MRZ-3a$^{sg(C)}$

Areas classified as MRZ-3a contain aggregate deposits, the significance of which cannot be evaluated from available data. Coarse-grained sedimentary units and resistant massive igneous and metamorphic rock units are often included in this category as potential sources of crushed stone. Criteria for geologic units to be classified as MRZ-3a include rock units that contain abundant, hard, durable material without excessive amounts of materials that are deleterious or reactive in concrete mixes.

Extensive regions of eastern and central Stanislaus County are classified as MRZ-3a$^{sg(C)}$ for aggregate, the largest expanse of which is in the San Joaquin Valley. Three general types of alluvial units are included in the San Joaquin Valley; (1) coalesced Coast Ranges alluvial fan debris (MRZ-3a$^{sg(C1)}$ through MRZ-3a$^{sg(C12)}$, Plate 2A), (2) regionally extensive Sierra Nevada sand deposits (MRZ-3a$^{sg(C14)}$, Plates 2B and 2C), and (3) the San Joaquin River channel and its associated flood-basin deposits (MRZ-3a$^{sg(C16)}$, Plate 2B). These combined areas contain many billions of tons of sediments that have weathered from rocks in the Sierra Nevada and Coast Ranges.

The thick Coast Ranges alluvial blanket along the western side of the San Joaquin Valley was deposited as a system of coalescing alluvial fans. Eleven distinct alluvial fans are shown on Plate 2A as MRZ-3a$^{sg(C2)}$ through MRZ-3a$^{sg(C12)}$. These fans contain Pleistocene and younger alluvium that is poorly sorted, unconsolidated to partially indurated, and has weathered from rock units within the Coast Ranges to the west. These eleven alluvial fans along the western margin of the San Joaquin Valley trough were formed when streams debouched their sediment loads onto the flat San Joaquin Valley floor.

Although portions of these eleven fans are classified MRZ-3a$^{sg(C)}$, aggregate quality varies from one fan to the next. These differences in aggregate quality are primarily the result of dissimilar rock types. Those fans with streams draining the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges tend to contain higher percentages of harder and more durable clasts than do fans that only drain Tertiary and Cretaceous sedimentary rocks. The relative aggregate potentials between these fans are presented in Table 5.

The eleven alluvial fans form an apex at the point where they emerge from the Coast Ranges and spread radially outward onto the floor of the San Joaquin Valley. The maximum sizes of fan sediments are generally much larger near the apex of the fan and gradually grade into finer-sized clasts--such as sand and silt--at the fan margins to the east near the San Joaquin River. Typically, over 95 percent of the clasts at the eastern-most extent of these alluvial fans are medium- and fine-sand sizes

Table 5. Relative potential of alluvial fans classified MRZ-3a in western Stanislaus County for containing economic deposits of concrete-grade aggregate.

ALLUVIAL FANS (from north to south)	PRINCIPAL SOURCE-ROCK UNITS DRAINED BY STREAMS THAT TRANSPORT WEATHERED SEDIMENTS TO ALLUVIAL FANS*					RELATIVE FAN POTENTIAL FOR CONTAINING ECONOMIC DEPOSITS OF CONCRETE-GRADE AGGREGATE
	Tertiary Sedimentary Rocks[1]	Moreno Formation[2]	Panoche Formation[3]	Coast Range Ophiolite[4]	Franciscan Complex[5]	
Hospital Creek Fan	X	X	X	X	X	High
Arkansas Creek Fan	X	X				Low
Martin Creek Fan	X	X				Low
Ingram Creek Fan	X	X	X		X	Medium-High
Kern Creek Fan	X	X	X		X	Medium
Del Puerto Creek Fan	X	X	X	X	X	High
Black Gulch Creek Fan	X	X				Low
Salado Creek Fan	X	X	X		X	Low-Medium
Little Salado Creek Fan	X	X	X			Low
Crow Creek Fan	X	X	X			Low
Orestimba Creek Fan	X	X	X	X	X	High

*Source-rock units are ranked by general durability of weathered materials: Relative durability increases from left to right across the table.

[1]Tertiary units primarily consist of generally soft, easily eroded sedimentary rocks of the Tesla Formation, Domengine Formation, Kreyenhagen Shale, Poverty Flat Sandstone, Valley Springs Formation, Neroly Sandstone, and fanglomerate. Weathered rock derived from these units generally does not make hard, durable, concrete-grade aggregate.

[2]The Moreno Formation primarily consists of interbedded shale and lesser amounts of fine-grained sandstone. Weathered rock derived from this formation generally does not make hard, durable, concrete-grade aggregate.

[3]The Panoche Formation primarily consists of moderately- to strongly-consolidated beds of sandstone, shale, and lesser amounts of conglomerate. Weathered rock derived from this formation (primarily sandstone clasts) is generally harder and more durable than clasts derived from the Moreno Formation or from the Tertiary sedimentary units.

[4]The Coast Range Ophiolite includes abundant mafic and ultramafic rocks, some of which are strongly serpentinized. Weathered rock derived from this unit makes hard, durable, concrete-grade aggregate.

[5]The Franciscan Complex includes abundant, resistant rock types that include metachert, greenstone, and metagraywacke. Weathered rock derived from this unit makes hard, durable, concrete-grade aggregate.

with silt and clay. Off-white carbonate coatings are locally common in deeper and older portions of these fans; some coatings are as thick as half an inch.

All of these alluvial fans have incised meanders that form washes, arroyos, and broad stream channels. An incised meander forms when a stream down-cuts into the fan surface. Because alluvial fan deposits are poorly sorted and interbedded with varying proportions of silt and clay, they typically require considerably more processing for use as concrete-grade aggregate than do stream-deposited alluvium.

At depth throughout the San Joaquin Valley, Coast Ranges alluvium interfingers with sediments weathered from the Sierra Nevada. Well log data shows that sediment sizes vary widely at depth throughout the San Joaquin Valley. Commonly, sediment clast sizes at the surface are sand-sized and finer, however, coarser gravel and cobble lenses occur at depth. Sediments within the San Joaquin Valley generally reach their maximum coarse-grained sizes at depths from 30-50 feet (Jay Noller, Lettis and Associates, personal communication, 1992).

Regionally extensive sand deposits weathered from the Sierra Nevada are typically hundreds of feet thick throughout the San Joaquin Valley within Stanislaus County (MRZ-3a$^{sg(C14)}$, Plates 2B and 2C). Generally, the uppermost 30-50 feet of alluvium is composed of sand, silt and clay with lesser amounts of rounded to well-rounded pea gravel and pebbles. The sand is arkosic, medium- to fine-grained and contains high percentages of quartz, feldspar and biotite. These sand deposits form the well-drained soils of central Stanislaus County and are an important agricultural resource. The parent soil material for the these valuable agricultural farmlands within Stanislaus County to the east of the San Joaquin River is the arkosic debris derived from the Sierra Nevada. Occasional deposits of medium- to fine-grained eolian dune sands also occur throughout the San Joaquin Valley trough (Plates 1B and 1C). Water well logs show occasional 3-15 foot-thick lenses of clay and unconsolidated conglomerate beds at depths of generally more than 30 feet.

Extensive thicknesses of the San Joaquin River channel and floodplain (MRZ-3a$^{sg(C16)}$, Plate 2B) have been intermittently mined in the past and primarily used as fill materials and as soil amendments in the fertile agricultural industry of Stanislaus County. However, aggregate producers, such as FTG Materials and Brown Sand, Inc., are currently mining San Joaquin River channel sand in San Joaquin County south of Manteca and report that the coarse 15-20 percent fraction of these sands can be processed and blended with coarser-grained-sized sands for use in gunite, stucco, mortar sand, roofing tiles, and plaster sand. To augment and extend decreasing concrete-grade aggregate resources identified within the MRZ-2 zones in this report, it may be

economically feasible to mine and process the coarser-sized fraction of these San Joaquin River channel sands in Stanislaus County.

MRZ-3a$^{sg(C1)}$ - Undifferentiated Coast Ranges Tertiary Fanglomerate (Plate 2A): These unconsolidated Pleistocene and Pliocene fan sediments occur along the eastern-most foothills of the Coast Ranges near the western edge of the San Joaquin Valley. This unit contains massive tonnages of sediments that have weathered from various rock units in the eastern Coast Ranges. Excavated road cuts and stream channel deposits, such as at Garzas Creek, show that this laterally extensive unit contains variable percentages of hard and durable clasts. This unit occurs as a series of cemented, interbedded conglomerates, sands and clays in Hospital Creek Canyon. Large amounts of red metachert cobbles and pebbles occur within the conglomerate units in Hospital Canyon, whereas much smaller percentages of these clasts occur within this unit in Del Puerto Creek Canyon to the south. North of Ingram Canyon and south of Del Puerto Canyon, this unit is predominately composed of cemented sandy and silty material with lesser amounts of cobble-sized material. The eleven identified creeks and their related fans along the western San Joaquin Valley contain sedimentary rocks that have weathered out of this unit.

MRZ-3a$^{sg(C2)}$ - Hospital Creek Fan (Plate 2A): Concrete-grade aggregate has been determined to exist within the MRZ-2a$^{sg(C1)}$ portion of this fan and there is also a likelihood that it exists within the MRZ-3a$^{sg(C1)}$ area of this fan. There is also a possibility that other commercially minable high-quality hard, durable and resistant concrete-grade aggregate exists at depth within this area of the fan. Much of the hard and durable clasts within this fan are transported by Hospital Creek from rock units in the regionally extensive Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Other, generally less durable sedimentary clasts within this unit are from the Panoche, Moreno, and Tesla formations (Table 5).

A local positive gravity anomaly was found in the vicinity of the Hospital Creek Fan apex. This anomaly may indicate an abundance of relatively dense metamorphic rock types from the Franciscan Complex and the Coast Range Ophiolite (Appendix C).

MRZ-3a$^{sg(C3)}$ - Arkansas Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Panoche Formation, Moreno Formation, Tesla Formation and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant

clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C4)}$ - Martin Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the relatively soft Valley Springs Formation, Tesla Formation, Neroly Sandstone and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C5)}$ - Ingram Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Franciscan Complex--especially from Franciscan Complex greenstone bodies--and from the Panoche Formation, Moreno Formation, Tesla Formation, Neroly Sandstone and the Tertiary fanglomerate unit. Because Ingram Creek drains generally more resistant and durable rock units within the Franciscan Complex, Ingram fan is a more favorable exploration target for concrete-grade aggregate resources than is the Martin Creek fan to the north or the Kern Creek fan to the south.

MRZ-3a$^{sg(C6)}$ - Kern Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Valley Springs Formation, the Tesla Formation and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C7)}$ - Del Puerto Creek Fan (Plate 2A): Base rock from this fan was mined in the 1950s and most probably used in the Delta-Mendota Canal. Del Puerto Canyon dissects the Coast Ranges nearly up to the crest. The source rock for the material in this fan is derived from sediments weathered from the Coast Range Ophiolite and Franciscan Complex high in the Coast Ranges. Lesser PCC-grade quality material within this fan is also derived from the Panoche Formation and Moreno Formation, with lesser amounts supplied from the Valley Springs Formation, Tesla Formation and the Tertiary fanglomerate unit.

A local positive gravity anomaly was found in the vicinity of the Hospital Creek Fan apex. This anomaly may indicate an abundance of relatively dense metamorphic rock types from the Franciscan Complex and the Coast Range Ophiolite (Appendix C).

MRZ-3a$^{sg(C8)}$ - Black Gulch Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Moreno Formation, Tesla Formation, Valley Springs Formation and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C9)}$ - Salado Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Panoche Formation, Moreno Formation with lesser amounts weathered from the Tesla Formation, Valley Springs Formation, and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C10)}$ - Little Salado Creek Fan (Plate 2A): The source of the sand and gravel within this fan is from weathered rocks of the Moreno Formation, the Tesla Formation and lesser amounts from the Panoche Formation and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C11)}$ - Crow Creek Fan (Plate 2A): The source of the sand and gravel within this fan is primarily from weathered rocks of the Panoche, Moreno, the Tesla formations with lesser amounts from the Valley Springs Formation and the Tertiary fanglomerate unit. Sedimentary clasts weathered from these units are generally not as hard or durable as are those that have weathered from rock units in the Franciscan Complex and Coast Range Ophiolite near the crest of the Coast Ranges. Consequently, the sand and gravel resources within this fan are not as likely to be of concrete-grade as are the more resistant clasts in the Hospital Creek, Del Puerto Creek, or Orestimba Creek fans.

MRZ-3a$^{sg(C12)}$ - Orestimba Creek Fan (Plate 2A): Concrete-grade aggregate has been mined from the Orestimba Creek Fan since the early 1900s; mining has been continuous since 1924. Concrete-grade aggregate is currently being mined in the MRZ-2a$^{sg(C2)}$ and

the MRZ-2b$^{sg(C2)}$ portions of this fan. It is potentially feasible that other commercially minable high-quality hard, durable and resistant concrete-grade aggregate also exists within the MRZ-3a$^{sg(C12)}$ area of this fan. Much of the sand and gravel within this fan is coarse-grained, chemical resistant and durable. The Orestimba Creek fan MRZ-3a$^{sg(C12)}$ area will likely be an important exploration target area of study for future concrete-grade commercial aggregate deposits.

The reason why this fan contains higher quality aggregate than do similarly-aged fans to the north is because Orestimba Creek swings east then northwards, capturing massive tonnages of high-quality hard, durable and more resistant weathered clasts that are transported out of the Franciscan Complex and Coast Range Ophiolite rock units near the crest of the Coast Ranges. In contrast, Crow Creek, Salado Creek, Little Salado Creek, and Black Gulch Creek to the north primarily derive their fan sediments from generally softer rock units such as the Panoche, Moreno, Tesla, and Valley Springs formations (Table 5).

MRZ-3a$^{sg(C13)}$ - Tesla Sandstone (Plate 2A): This predominately fine-grained, quartzose sandstone unit is classified as MRZ-3a for concrete-grade aggregate because it may be used in the future to augment more coarse-grained clasts for use in concrete products. This moderately indurated sandstone unit is characteristically weakly-cemented with abundant cross-beds. It formed from sands weathered from the ancestral Sierra Nevada and deposited in shallow Paleogene seas that covered this region. In places this unit appears stark white and contains nearly 100 percent fine- to medium-grained quartz sands.

MRZ-3a$^{sg(C14)}$ - Pliocene and younger alluvium (Plates 2B and 2C): This expansive zone includes the following sedimentary formations of Pliocene and younger age; Laguna Formation, the North Merced Gravel, Turlock Lake Formation, Riverbank Formation, Modesto Formation, and post-Modesto alluvium (see Plates 1B and 1C for the exact areas of these units). The sedimentary rocks within this classified zone predominately contain varying proportions of fine- and coarse-grained alluvium. All of these sediments form elevated river terraces and fans associated with the massive tonnages of alluvium that have drained from the Sierra Nevada during the past 4 million years. Surface deposits of this alluvium west of Modesto to the San Joaquin River channel are characterized by less than 20 percent medium- and fine-grained sand sizes. At depths of 20-50 feet, however, the percentages of medium-grained sands and coarser-sized clasts rise to more than 40 percent (Laudon and Belitz, 1991).

Three active streams of note that drain the northeastern portion of Stanislaus County that are included in this classified area are Rock Creek, Shirley Creek, and Hoods Creek. All three creeks contain unconsolidated hard and durable Holocene sand and

gravel deposits that generally range in thickness from a few inches to more than 5 feet. Sand and gravel has been intermittently scalped from the active channels of Shirley and Hoods creeks since the 1920s for use in road construction. Although the aggregate from these creeks is of concrete-grade, these areas have not been classified as MRZ-2a$^{sg(C)}$ or MRZ-2b$^{sg(C)}$ because they do not meet the minimum threshold value.

MRZ-3a$^{sg(C15)}$ - Stanislaus River alluvium (Plates 2B and 2C): Stanislaus River channel alluvium at the McHenry Avenue Bridge is composed of 80 percent or more of sand, silt and clay. Percentages of fine-sand and silt increase from the McHenry Avenue Bridge westward. At the confluence of the Stanislaus and San Joaquin rivers, the grain size at the mouth of the Stanislaus River is generally composed of less than 30 percent medium- to fine-sized sand; the remaining material is silt and clay. In the 1950s and 1960s unconsolidated coarse- to fine-grained sand was mined for use as plaster sand by the Modesto Sand and Gravel, Co. from elevated Stanislaus River terraces at Ripon. Occasional 2-3 foot lenses of pebble- and coarser-sized clasts occur along the banks of the active Stanislaus River channel in this area.

MRZ-3a$^{sg(C16)}$ - San Joaquin River alluvium and associated floodplain deposits (Plate 2B): Unconsolidated Holocene fine-grained San Joaquin River alluvium predominately consists of medium- to fine-grained sands, silt, and clay with rare, thin (1-3 foot thick) lenses of pebbles and coarse sands. Floodplain deposits range in thickness from 5-35 feet and typically contain less than 20 percent coarse-grained sand. Higher percentages of sands and coarser-sized clasts occur at depths between 20-50 feet in this zone (Laudon and Belitz, 1991).

MRZ-3a$^{sg(C17)}$ - Tuolumne River alluvium (Plates 2B and 2C): In the 1930s and 1940s sand and gravel was mined from in-channel portions of the Tuolumne River in areas to the west of Geer Road near Modesto. Most of the Tuolumne River from Empire west has since been depleted of aggregate; however, the few sites where significant amounts of aggregate remain west of Empire are shown on Plates 2C and 3. Clast sizes decrease from predominately in-channel cobble and pebble-sized clasts in this area east of Modesto, westward towards the confluence of the Tuolumne and San Joaquin rivers, where in-stream clasts are predominately sand- and finer-sized.

MRZ-3a$^{sg(C18)}$ - Ione Formation (Plate 2C): Angular medium- to fine-grained quartzose sandstones have been extracted from the Ione Formation since the early 1860s and used as glass sand. These sandstone beds are interbedded with kaolinitic claystones. The Ione Formation may contain local lenses of conglomerate or well-cemented sandstone beds at depth.

CRUSHED STONE (concrete aggregate)

Areas classified for crushed stone resources in Stanislaus County are shown on Plates 2A and 2C. The classified areas are identified by the following superscript: $^{cs(C)}$ indicating "crushed stone (Concrete grade)." Superscript reference numbers are used to identify specific MRZ-3a deposits discussed in this section. For example, MRZ-3a$^{cs(C3)}$ identifies specific greenstone bodies within the Coast Ranges that are classified as MRZ-3a for concrete-grade aggregate. Deposits of a given classification type are numbered from west to east and from north to south across each plate.

Areas Classified MRZ-3a$^{cs(C)}$

MRZ-3a$^{cs(C1)}$ - Panoche Formation (Plate 2A): This marine Late Cretaceous unit is predominately composed of massive moderately indurated and slightly- to moderately-cemented siltstone and sandstone units interbedded with 40-foot thick moderately-indurated shale units. Locally, there are 20- to 35-foot-thick, well-cemented conglomerate beds.

MRZ-3a$^{cs(C2)}$ - Coast Ranges metachert (Plate 2A): Metachert is common within the Franciscan Complex and typically occurs as 2-5 inch-thick beds of dark brick-red, green and gray metachert beds interbedded with much thinner shale strata. The interbedded metachert and shale strata commonly range in thickness from 15-40 feet within roadcuts along the Del Puerto Canyon Road. Franciscan Complex metachert has been mined in the Coast Ranges of California for use as aggregate since the 1960s.

MRZ-3a$^{cs(C3)}$ - Coast Ranges greenstone (Plate 2A): Some of the most extensive occurrences of greenstone in California occur within the Coast Ranges Franciscan Complex. Greenstone is commonly mined in the Sierra Nevada foothills and in the Coast Ranges of California for use as crushed aggregate. Greenstone bodies are abundant in the Franciscan Complex of western Stanislaus County.

MRZ-3a$^{cs(C4)}$ - Sierran foothills basement rocks (Plate 2C): This zone includes an assortment of metamorphosed Cretaceous and Jurassic marine sedimentary and igneous rock types that occur as outcrops along the eastern boundary of Stanislaus County and form the lowest extent of the Sierra Nevada foothills. Surface exposures of these rocks are highly weathered, fractured and jointed. These units have the potential of being used for future sources of concrete-grade crushed aggregate.

MRZ-3a$^{cs(C5)}$ - Table Mountain Latite (Plate 2C): This 9 million-year-old porphyritic olivine-augite latite lava flow is currently being mined by George Reed, Inc. at its Table Mountain Quarry, located about 6 miles northeast of Knights Ferry, in Tuolumne

County. The latite is quarried, crushed and sized for use as AC aggregate and road base. Some of the quarried latite is consumed within Stanislaus County. Surface exposures of the Table Mountain latite in Stanislaus County are extensively weathered. However, at depth this material is unweathered and may provide future sources of AC crushed aggregate.

AREAS CLASSIFIED FOR INDUSTRIAL MINERALS

INDUSTRIAL MINERALS IN GENERAL

MRZ-1^{i} - Western and Central County (Plate 4A and 4B): Included in these areas are the region between the Coast Ranges and Sierra Nevada foothills and the region underlain by the Volcanic Member of the Coast Range Ophiolite. These areas are not expected to have significant deposits of industrial minerals in general. The large Great Valley region is underlain by alluvial deposits that are noted only for their deposits of aggregate as described in preceding sections. Excluded from this category are common clay and zeolites as will be described below.

MRZ-4^{i} - Western and Eastern County (Plate 4A and 4B): These areas are present in two widely separate regions. The western region is entirely underlain by Franciscan Complex, the lithology and structure of which are too complicated and insufficiently mapped to rule out the presence or absence of significant deposits of industrial minerals in general. For example, the Franciscan has been mined for limestone in other parts of the Coast Ranges, but this commodity has not been recognized in Stanislaus County with the exception of a few minor outcrops. Similarly, expansible shale may be present, but the character of the shale units of the Franciscan in Stanislaus County was not sufficiently studied to rule out the presence or absence of significant deposits of this commodity.

The eastern region, along the county line, consists of a few small areas underlain by either Table Mountain Latite or what is interpreted to be Great Valley Sequence. The latite unit may or may not overlie significant deposits of industrial minerals associated with the Ione Formation or crystalline basement. The exposures of Great Valley Sequence were not visited; consequently, the presence or absence of industrial minerals was not determined.

BENTONITIC CLAY

MRZ-3b$^{i(B)}$ - Western and Eastern County (Plate 4A and 4B): The Valley Springs Formation, which underlies these areas, is composed mainly of claystone, tuffaceous claystone, and silicic

tuff. It is exposed on both edges of the Great Valley. The more extensive exposure is in the east, where it forms an irregular northwest-trending band of very shallow-dipping outcrops near and within the Sierra Nevada foothills. In the west, it is similarly exposed in a northwest-trending band of moderate- to shallow-dipping outcrops within the range front of the Coast Ranges.

Because of its silicic tuffaceous character, this formation may contain horizons of material altered to bentonitic (smectite) clay. None have been conclusively recognized, however, either in this or other studies. Bacon (1963) mentions "bentonitic clays" in the Valley Springs in the Coast Range exposures, yet this was not verified in the present study. Observations of a few cuts along the California Aqueduct in the Coast Ranges revealed claystone with a rough, cracked texture and a waxy luster, suggestive of low-swelling bentonite (Patterson and Murray, 1983). Similar properties were observed in cuttings from holes believed to penetrate the Valley Springs in the Cooperstown-La Grange area in the Sierra Nevada foothills.

X-ray diffraction analysis of a sample of Coast Range claystone showed smectite and lesser amounts of kaolinite with some volcanic glass (Appendix B; Table B-6). Analysis of a Sierra Nevada sample showed mostly glassy material. The presence of glass in the strata observed is undesirable and may be pervasive enough throughout the formation to reduce its mineral potential considerably. Considering the above information, neither the presence or absence of bentonitic clay in the Valley Springs is verified, although the geologic environment is favorable for its presence. The western boundary of the Sierra Nevada MRZ area was determined by estimating an economic limit of overburden on top of the Valley Springs.

DIATOMITE

MRZ-2b$^{i(D1)}$ - Crow Hill (Plate 4A): The most important known resource of diatomite in the county, this area has been mined sporadically during this century, most recently by H.C. Muddox Company of Sacramento for flue pipe in residential fireplaces. At least nine separate open-pit mines (81-89) are present in this area. Total tonnages produced are estimated to be less than 100,000 short tons.

The diatomite is shaley, very light in weight, off-white to pale tan (Appendix B, Table B-7), and dips at shallow angles to the east. It forms a barrens-type landscape, characterized by gray soil and very sparse vegetation. The extent of this landscape suggests that the diatomite underlies a substantial area beyond the immediate mined area.

Advantages of the diatomite in this area for mining include the large tonnages available, softness of the material, the shallow angle of dip, and its extensive exposure at the ground surface. Thickness of the Kreyenhagen Shale is reported by Bartow and others (1985) to be up to 1,000 feet in this region. Additionally, access is near Interstate 5, yet the area is substantially hidden from view by the rolling hills.

An important disadvantage of the material is the common presence of clastic sandstone dikes, which cut the diatomite in many orientations. The dikes range from inches to feet in thickness and were observed throughout the area. Selective mining is necessary to avoid the dike material. Another potential disadvantage of the diatomite is its clay (smectite) content (Appendix B), although this could be advantageous for use of the diatomite as a filler or an absorbent. As clay content increases, the color of the diatomite assumes subtle pink, tan, and greenish casts. Gypsum, another deleterious substance for some applications was observed in a few places.

MRZ-3a$^{i(D1)}$ - Crow Creek (Plate 4A): Situated north of Crow Creek, this area is an extension of the Kreyenhagen Shale exposed at Crow Hill. Localities underlain by diatomite similar to that described above are exposed sporadically here. Dips of the strata are shallow. None of the area has been mined, however. Furthermore, observations made during this study were of insufficient number to classify it as MRZ-2. Sample STC-14a (Appendix B) was collected from this area.

MRZ-3a$^{i(D2)}$ - South of Crow Hill (Plate 4A): This area adjoins the Crow Hill area on the west and is characterized by almost no outcrop of the Kreyenhagen Shale. Diatomite was recognized in animal burrows, but the significance of the area could not be determined because of general lack of exposure. In addition, Bartow and others (1985) reported the lower part of the Kreyenhagen, which is present in this area, to be composed of sandstone.

MRZ-3a$^{i(D3)}$ - South of Orestimba Creek (Plate 4A): An extensive area of Kreyenhagen Shale is mapped along and west of the California Aqueduct, south of Orestimba Creek. Diatomite has not been mined here, yet observations made along the aqueduct indicate that at least part of the formation has characteristics similar to the Crow Hill area: Dips of the strata are shallow to the east, the diatomite is off-white to pale tan in color and of low density, and sandstone dikes are common. Beyond the aqueduct, however, the terrain is subdued and outcrops are uncommon. Consequently, observations were insufficient to determine if this area has significant deposits of diatomite.

RESIDUAL KAOLINITIC CLAY

MRZ-3a$^{i(RK)}$ - Southeastern Sierra Nevada Foothills (Plate 4B): Several local areas of the exposed metamorphic basement in the Sierra Nevada foothills have zones of residual clay (saprolite). These zones represent sites of intense chemical weathering that probably developed during the early Cenozoic. The weathering caused leaching of many elements from the metamorphic rock and, depending on the intensity of weathering and the original composition of the rock, left behind various proportions of iron, silica, and clay minerals such as kaolinite, smectite, and illite. Consequently, the zones of saprolite are irregular in geometry, chemistry, and distribution, and are thus commonly difficult to evaluate as potential sources of kaolinitic clay. In some places, close inspection of outcrops and roadcuts shows that what may at first appear to be clay of the Ione Formation is really saprolite of the basement complex. Such confusion is not unexpected, as much of the clastic material that comprises the claystone and sandstone of the Ione was originally derived from saprolitic areas of the Sierra Nevada basement (Allen, 1929).

Each of the individual classified areas in this group have known deposits of residual kaolinitic clay. The residual nature of many can be recognized by the presence of remnant metamorphic foliation. In the area immediately east of Cooperstown are three open pits (160-162) that have been mined for clay; all are in cream-colored to white, intensely leached, foliated metamorphic rock. A sample from one pit was estimated to contain about 68 percent quartz and 30 percent kaolinite. (Appendix B). It is possible this area represents an intensely weathered zone of basement that was originally hydrothermally altered.

MRZ-3b$^{i(RK)}$ - Sierra Nevada Foothills (Plate 4B): This group comprises all of the areas of the exposed Foothills Terrane not known to have deposits of residual kaolinitic clay. Each of the areas, however, are favorable geologic environments for the presence of deposits similar to those described above. Any deposit discovered will have unique physical and chemical properties that will suit it to particular applications, which can only be determined by specific tests.

SEDIMENTARY KAOLINITIC CLAY ONLY

MRZ-2a$^{i(K1)}$ - Kraftile Pit Northwest of La Grange (Plate 4B): This area includes the Kraftile Pit (196), which was idle in 1992. It is a good example of how significant deposits of kaolinitic clay may be concealed beneath the horizons of sandstone and conglomerate of the Ione Formation in Stanislaus County. Before mining, this area showed no evidence of any claystone except for a small amount (1-foot thick) in a roadcut. Shallow borings and approximately 40 holes drilled with a bucket-type rig later

revealed a lensoidal deposit of claystone with measured reserves of over 250,000 tons of ball clay (Wild and Key, 1963). Kraftile Company of Fremont, California, began mining this deposit in 1959 to blend with other clays for the manufacture of structural tile. Operations continued until the middle 1980s when Kraftile surrendered its lease because, among other reasons, the company decided the deposit contained too much silica for tiles. Total production from the pit was probably less than 50,000 tons, which would leave at least an estimated 200,000 tons of reserves.

The drill-hole data indicate that the claystone body is lensoidal, with a flat top and saucer-shaped bottom, the latter caused by the irregular surface of deposition. Such a geometry is typical of the local deposits of Ione claystone. Thickness of the mineable horizon is up to 26 feet. Maximum overburden is up to 30 feet and may reach as much as 50 feet locally. Drill-hole data also indicate that the deposit continues east of the pit area, which justified our extension of the boundary of the MRZ in that direction.

Physical properties of the clay deposit are well-documented in both Wild and Key (1963) and Padan (1963). Clay exposed in the pit ranges from gray to tan. Chemical properties are indicated by sample STS-35 (Appendix B), the most notable of which is the elevated silica content.

MRZ-2b$^{i(K1)}$ - 49er Pit Northwest of Cooperstown (Plate 4B): This area is situated along Rock River Road at the county line and, if extended over the line, would include the nearby Hornsby Pit (Plate 8C). The boundary of this area was determined from both drill-hole data (Plate 11) and the presence of the 49er (Rodden Ranch) Pit (155), which was mined for kaolinitic (ball) clay in the Ione Formation.

The 49er Pit began operation about 1960 and recently ceased operation when its high-grade stockpile was depleted. Total production is estimated to be less than 25,000 tons. The stockpile consisted of mottled chocolate-brown, organic-rich clay, which was reportedly used in sanitary ware because of its plastic properties (Doug Merrill, Kelly-Moore Paint Company, personal communication, 1993). Sample STS-RR (Appendix B) was taken from this material. Physical properties of this material are described in Padan (1963).

Also on the 49er site are overburden stockpiles, which contain several thousand tons of lower-grade clay. This material contains abundant limonite and fragments of quartz and metamorphic rock. It might be used for a low-end application where high impermeability is a desired characteristic. A chemical analysis (STS-46) of this material is presented in Appendix B.

Data from hole 10 (Plate 11) indicate that the claystone mined above continues in the subsurface to the southwest. Approximately 70 feet of claystone described as "brown" and "lignitic" were revealed in this hole. We thus infer from these data that a significant deposit of kaolinitic clay underlies this area, which could have characteristics similar to that mined at the 49er Pit.

MRZ-2b$^{i(K2)}$ - Curtoni Pits Southeast of Cooperstown (Plate 4B): This area is another example of a concealed clay deposit, similar to the Kraftile Pit area described above. It includes the Curtoni Pits (165-169), which are the sites of the largest production of kaolinitic (ball) clay in the county.

The area is characterized by the typical rolling terrain underlain by sandstone and conglomerate of the Ione Formation. Beneath these horizons, a thick (>25 feet) horizon of kaolinitic claystone is present, which was first mined at least as early as the 1950s. Here, 5 pits were excavated, but only two (165,167) had large production. Based on size of the pits, we estimate cumulative production to be more than 50,000 tons. Most was apparently used for the manufacture of sanitary ware. The last operation at the pits was in the 1980s, when stockpile was removed by H.C. Muddox Company for the unsuccessful manufacture of white bricks.

One of the Curtoni Pits (167) reveals a good stratigraphic section of the Ione Formation. Here, approximately 12-15 feet of mottled ferruginous sandstone and conglomerate overlie a minimum of 20-25 feet of kaolinitic claystone. The claystone is pale brown, weathering to a light gray. The exposed surface of its upper part is stained with limonite derived from the overlying sandstone. Internally, however, the claystone is very clean, with little sand or deleterious material evident in hand specimen. Chemically, the claystone has the highest kaolinite content and one of the lowest silica contents measured on samples from the county (Appendix B).

The exposures of thick claystone in the Curtoni Pits suggest that a significant deposit of kaolinitic clay is present under much or all of this area. Despite the absence of available drill-hole data, we infer that the lens of claystone extends laterally under the adjacent hills, which are commonly capped by sandstone and conglomerate. Although much clay has been mined, we infer that there are probably sufficient tonnages here to meet the minimum requirements for classification of the area as MRZ-2b.

MRZ-2b$^{i(K3)}$ - Northwest of La Grange (Plate 4B): Situated along Cooperstown Road, this area is underlain by Ione Formation that is capped in places by Valley Springs Formation and Quaternary alluvium. Part of the area was interpreted by Padan (1963) to be a virgin area of clay deposits, which was not recognized until

the drilling project of the early 1960s. The area has never been mined and is presently the site of an abandoned residential development. Claystone is exposed locally in excavated areas.

Several holes drilled in this area (Plate 11) reveal a few tens of feet of gray to brown claystone that is composed dominantly of quartz and kaolinite; generally, there is little or no sand-sized material in the claystone. Abundant organic material was found in hole 33.

Chemical analyses of this claystone from holes 21 and 34 (Appendix B) show amounts of kaolinite and quartz similar to those in other clay horizons studied in other parts of the county. Of note is the similarity of the sample from hole 21 to that analyzed from the Curtoni Pit (STS-7). These two samples had the highest ratio of kaolinite-to-quartz measured.

We believe that both the density of drill holes and the thickness of good-quality kaolinitic clay horizons observed in them are sufficient in this area to justify classification of the area as MRZ-2b.

MRZ-3a$^{i(K1)}$ - Northwest of Cooperstown (Plate 4B): As determined from logs of several drill holes (Plate 11), this area overlies substantial thicknesses of clay. It is not clear in places, however, how much of the clay is part of either the Ione Formation or Valley Springs Formation. Furthermore, parts of the logs are too ambiguous to determine any lateral continuity between recorded horizons. A few horizons less than 100 feet deep in holes 1 and 7 are reported on the logs to be of "good" quality, but the strong smectite peaks observed on X-ray diffraction patterns suggest these intervals may be Valley Springs Formation.

SEDIMENTARY KAOLINITIC CLAY AND SPECIALTY SAND

MRZ-3b$^{i(K,S)}$ - Southeastern Sierra Nevada Foothills (Plate 4B): In these areas, we estimate the depth to the top of the Ione Formation, which is covered by younger sedimentary and volcanic rocks, to be no more than 100 +/- 50 feet. This figure represents a conservative depth limit for economic removal of overburden during mining and is based on both drill-hole information, present topography, and projection of a shallow-dipping, flat planar surface that represents an ideal uneroded top of the Ione. The error allows for the eroded character of the top of the Ione as well as variation in the present-day topography. In places, erosion may have cut entirely through the Ione, such that it may be absent in the subsurface. Nevertheless, we believe the subsurface of these areas is a favorable geologic environment for the presence of both sedimentary kaolinitic clay and sandstone that could be used for specialty purposes.

SEDIMENTARY KAOLINITIC CLAY AND DIMENSION STONE

MRZ-3a$^{i(K,St)}$ - Cooperstown Area (Plate 4B): The two areas of this group coincide with those classified as MRZ-2b for specialty sand. Deposits of both kaolinitic clay and indurated sandstone of the Ione Formation are present. Depending on physical and chemical properties of the deposits, the clay might be suitable for a variety of specialty purposes, while the sandstone might be suitable as dimension stone.

SEDIMENTARY KAOLINITIC CLAY, SPECIALTY SAND, AND DIMENSION STONE

MRZ-3a$^{i(K,S,St1)}$ - Knights Ferry (Plate 4B): These two areas are underlain by Ione Formation, which consists of claystone and sandstone. Both rock types are well-exposed in the Winkler Pit (149), which is just northeast of Knights Ferry. Here, a claystone horizon, perhaps as much as 25 feet thick, underlies a sequence of bedded fluvial quartzose sandstone, both of which dip gently to the west. The claystone is massive, tan (weathering to gray), and has small fragments of carbonaceous material. Its X-ray diffraction pattern is similar to other ball clays in the Stanislaus area, although its kaolinite peak is noticeably sharper and higher than the other samples shown in Appendix B. Immediately over the claystone is a thin cap of limonitic jasper, which gives way to indurated sandstone composed of quartz, kaolinite, and mica. The sandstone is more ferruginous and indurated at the base and becomes softer and less ferruginous above.

Tonnages of clay mined at the Winkler Pit are unknown, but probably were in the thousands of tons. The remaining claystone appears to be of good quality. We were unable to classify this deposit as significant, however, because of the absence of control on lateral continuity of either the claystone or sandstone. Even so, the thickness of both units suggests that the deposits may be laterally extensive, which can only be verified by drilling in the immediate area.

The northern area does not have abundant outcrops, but there is evidence of indurated sandstone, which was quarried at one site (152) for dimension stone.

MRZ-3a$^{i(K,S,St2)}$ - Cooperstown (Plate 4B): Just west of Cooperstown are several areas underlain by Ione Formation that consists largely of sandstone and minor conglomerate at the surface. Many outcrops of sandstone are well-indurated and variegated, with different shades of red and yellow. Several quarries were once operated here to extract such material for use as dimension stone for local buildings and possibly decorative rock. A few drill holes in these areas indicate both kaolinitic claystone and quartzose sandstone to depths of at least 75 feet.

MRZ-3a$^{i(K,S,St3)}$ - Southeast of Cooperstown (Plate 4B): Similar to those described above, these two areas are underlain by Ione Formation, which is characterized here by a rolling topography that is subdued in places. Typically, outcrops are the well-indurated sandstone and conglomerate prevalent elsewhere, which might be suitable in places for building stone. Exposures of claystone and softer sandstone are also present locally. Parts of these areas are also adjacent to the Curtoni Pits (165-169) described above; the clay horizons mined in these pits may extend laterally into these parts, but this speculation can only be verified by drilling.

The nature of the geologic contact between parts of the Ione and the underlying basement rock here also demonstrates that the Ione was deposited on an irregular surface; consequently, thicknesses of the Ione horizons can vary laterally. A few drill holes reveal the Ione in the subsurface (Plate 11).

MRZ-3a$^{i(K,S,St4)}$ - Northwest of La Grange (Plate 4B): These two areas are underlain by kaolinitic claystone and sandstone of the Ione Formation, which is generally exposed at the surface. Small parts do not have Ione at the surface, but geologic evidence and drill-hole data indicate it is present at very shallow depth. As elsewhere in the Ione, sandstone and conglomerate form the prominent outcrops because of their well-cemented character; they are also known to conceal bodies of claystone, which, because of its softer character, tends to crop out poorly or not at all. The bodies of claystone appear to be lensoidal. Outcrop patterns of the Ione suggest it may be only a few tens of feet thick in places.

Chemical analysis (Appendix B) of two samples from these areas show about equal amounts of quartz and kaolinite in the claystone, similar to that of the Kraftile Pit described above. This result suggests that the Ione claystone in these areas may have a relatively high quartz content in general, which could affect its potential applications.

One of the best cross-sectional exposures of the Ione in the county is exhibited in an open pit (201) north of La Grange. Here, a section about 40-50 feet thick reveals a stratigraphy very similar to that at the Winkler Pit at Knights Ferry. A light gray claystone at least 12 feet thick is overlain by 6-10 feet of white to light gray argillaceous fine-grained sandstone and siltstone, which in turn are overlain by about 20 feet of ferruginous sandstone and pebbly conglomerate. This section appears to be typical in a general way for the Ione in Stanislaus County, and may be a local representation of a major environmental transition from earlier brackish estuarine conditions (claystone) to later nonmarine fluvial conditions (sandstone, conglomerate). Significantly, if this interpretation is correct, the extensive areas of Ione sandstone in the county

may conceal many more lenses of claystone than are apparent at the surface.

Logs from a few drill holes (Plate 11) show subsurface horizons of both claystone and sandstone in the Ione, yet the holes are spaced too far apart to allow determination of lateral continuity of the horizons. Nonetheless, although the two areas are classified MRZ-3a, we conclude that evidence from several additional well-placed drill holes in the areas would likely justify reclassification of parts of them to MRZ-2b.

MRZ-3a$^{i(K,S,St)}$ - Sierra Nevada Foothills (Plate 4B): This group consists of several areas distributed from just north of Knights Ferry, south to the Merced County line. They are underlain by Ione Formation, which generally is exposed at the surface or, in a few instances, is present in the shallow subsurface (<100 feet), as indicated by logs of drill holes (Plate 11). These areas were studied in the field only briefly or not at all.

Typically, these areas have somewhat subdued topography, with indurated sandstone and conglomerate at the surface. Because of their resistance, these rocks tend to prevent exposure of underlying bodies of claystone and softer kaolinitic sandstone. Nonetheless, each of these is known or expected to be present in these areas.

MAGNESITE

MRZ-3a$^{i(M1)}$ - Red Mountain and Adobe Canyon (Plate 4A): Situated along the headwaters of Del Puerto Creek, this area encompasses much of the Alpine Peridotite Member of the Del Puerto Ophiolite (Plate 1A). Also included is the Red Mountain District, the most productive magnesite district in California. Site of the famous Western Mine in adjacent Santa Clara County, the district straddles the county line through Red Mountain, a prominent landmark underlain by ultramafic rock of the harzburgite unit. The mountain is riddled with veins and replacement bodies of high-brightness, high-purity magnesite that occupy faults and shear zones in the serpentinized harzburgite. Within this MRZ, the summit and flanks of Red Mountain have the highest potential for finding new deposits of magnesite.

On the flanks of Red Mountain within Stanislaus County, the most important production of magnesite has come from the Red Mountain (Patterson) Mine (23-26). Deposits here are typical of those elsewhere on Red Mountain, particularly the northerly trend and steep-to-vertical dip of the vein system. The magnesite is bright white and of high purity (Appendix B). Estimates of production range from 70,000 to 140,000 tons (Bodenlos, 1950; U.S. Bureau of Mines, 1943). The amount of reserves left is

controversial (Bodenlos, 1950; U.S. Bureau of Mines, 1943), but is probably no more than 50,000 tons.

In the Adobe Canyon area to the southeast, there are many occurrences of magnesite in the serpentinized ultramafic rock. Generally, these are in the form of small veinlets, crusts, and nodules, many of which are probably more properly termed "hydromagnesite," which is the water-bearing form of magnesite. No mines or prospects are known in this area, however.

Because of the hydrothermal origin of these deposits, their distribution is erratic and often unpredictable. Even known deposits are commonly not well-defined as to their reserves. Furthermore, Bodenlos (1950) noted that the magnesite, including some of the largest veins and replacement bodies, generally crops out poorly or not at all. Consequently, large deposits may be present in the subsurface, but are not recognizable at the ground surface. Regarding depth of the veins, magnesite tends to form in shallow levels of the crust. For example, Bodenlos (1950) reported the deepest vertical extent of known veins in the Red Mountain District to be 660 feet. For these reasons, and the lack of reliable data on reserves, we were unable to determine the significance of the deposits of magnesite in this area.

MRZ-3a$^{i(M2)}$ - Arkansas Canyon (Plate 4A): Situated along the north side of Del Puerto Creek, this zone is characterized by intensely sheared serpentinite. A small prospect (72) reveals small veinlets and nodules of magnesite disseminated in the serpentinite. Insufficient observations were made, however, to determine either the presence or absence of significant deposits of magnesite.

MRZ-3a$^{i(M3)}$ - Slick Rock Canyon (Plate 4A): Similar to the Arkansas Canyon area, this zone is characterized by serpentinite that is intensely sheared, mainly because of its location along the Tesla-Ortigalita Fault Zone. Two prospects (75, 76) reveal pervasive replacement of the serpentinite by small veinlets and nodules of magnesite. As at Arkansas Canyon, however, the erratic distribution of the magnesite and the small number of observations made did not allow us to determine either the presence or absence of significant deposits of magnesite.

MRZ-3a$^{i(M4)}$ - South Fork of Orestimba Creek (Plate 4A): This area encompasses an east-west-trending body of serpentinite that is either an outlying fragment of Coast Range Ophiolite or a large tectonic block within Franciscan Complex. The body is intensely sheared and shows small concentrations of magnesite here and there. Unpublished property reports by consultants indicate some magnesite prospects are present in the body, although these were not verified during our field study of the area. Observations were insufficient to determine the significance of the magnesite deposits in this area.

MRZ-3a$^{i(MS)}$ - Bald Eagle Mine (Plate 4A): This area comprises an elongate northwest-trending strip of serpentinite along the Tesla-Ortigalita Fault Zone. The serpentinite is intensely sheared because of movement on the fault, which has also resulted in landslides along the zone. Within one of these landslides is the Bald Eagle Mine (96-98), which is the most productive magnesite mine in Stanislaus County. The mine consists of a large number of surface and underground workings developed in irregular masses of magnesite that replace the serpentinite. Operations ceased in the 1940s reportedly because reserves were depleted. Total production is unknown, but based on the size of the dumps, it is inferred to be larger than that of the Red Mountain Mine.

A few miles northwest of the Bald Eagle is a group of adits (95) driven into the serpentinite unit. Little is known about this deposit (access was denied), but its character is probably similar to that of other magnesite deposits in the county.

The nature of the serpentinite unit is interpreted to be similar to others along the Tesla-Ortigalita Fault Zone as described above. Deposits of magnesite are expected beyond the two properties mentioned, yet whether or not any of these deposits are significant is undetermined.

MRZ-3b$^{i(M)}$ - Western Coast Ranges (Plate 4A): Other bodies of serpentinite are exposed in several places throughout the western Coast Ranges. Some of these are fault-bound fragments of Coast Range Ophiolite. Others are tectonic blocks of the Franciscan Complex, wedged along faults between terranes or incorporated within melange. None of these bodies have known deposits or indications of magnesite, yet they represent favorable geologic environments for its occurrence. Hydrothermal activity, which caused the alteration of serpentinite locally to magnesite, was common over the entire western Coast Ranges area and could easily have affected any one of the serpentinite bodies described here. Furthermore, those bodies along fault zones, such as the Tesla-Ortigalita, may have particular potential because the zones are commonly channels for the movement of hydrothermal fluids.

Several areas adjacent to or in the vicinity of mapped exposures of serpentinite are favorable geologic environments for the presence of concealed or unmapped bodies of serpentinite. Such areas might also contain deposits of magnesite.

Two small areas near Quinto Creek may or may not have significant deposits of magnesite associated with them. The two areas, which were not visited, are classified based on positive aeromagnetic anomalies as shown on Plate 10. Geologists have not reported serpentinite at either area, yet the coincidence of very strong aeromagnetic highs with bodies of serpentinite in the surrounding region suggests that both areas may be underlain by serpentinite at or near the ground surface.

QUARTZ (silica)

MRZ-2b$^{i(Q1)}$ - Hammond Mine Quartz-Vein Complex (Plate 4A): In Del Puerto Canyon is a complex system of white quartz and calcite veins injected into the Plutonic Member of the Coast Range Ophiolite. The complex is as wide as about 40 feet, but the main mass of veins ranges from about 3 to 20 feet. The complex strikes northwest and dips steeply northeast. It is exposed from the bottom of Del Puerto Creek for a distance of at least 1,500 feet to the southeast. To the north, the complex disappears under a landslide. It appears that the calcite veins, which are less extensive, are younger than the quartz veins. Both types are characterized by coarsely crystalline texture.

A small adit has been developed on the vein complex where it is intersected by Del Puerto Canyon Road; reportedly some quartz was shipped during the 1940s for use in the steel industry. Chemical analyses (Appendix B) indicate that the quartz is high purity silica, although in one sample a few grains of chalcopyrite were observed.

The length, width, and chemistry of the vein complex suggest that it could be a locally important source of silica for some type of industrial use, although the presence of the calcite veins reduces the quality of the deposit to some degree. Past exploitation has probably been hindered most by relative isolation of the deposit and the lack of a local market.

SPECIALTY SAND ONLY

MRZ-2b$^{i(S1)}$ - South of Orestimba Creek (Plate 4A): Situated along the California Aqueduct, this zone is underlain by a very clean, white sandstone horizon of the Poverty Flat Sandstone. Tonnages in this zone are sufficient to meet the criteria of a "significant" industrial-mineral deposit; the Mineral Resource Zone boundary is conservative and could probably be expanded by additional study and sampling. A local resident reported that this deposit was explored with a few drill holes several years ago, but we were unable to find any additional information on the holes.

The character of the sandstone is best displayed in the cuts adjacent to the aqueduct. The best material observed consisted almost exclusively of fine- to medium-grained quartz in a matrix of white kaolinite. We estimate the percentages to be 81 percent quartz and 17 percent kaolinite (Appendix B). The quartz is very clear and angular to subangular, similar to that observed in the Ione Formation to the east. Rock fragments are less than one percent and a few grains of altered feldspar are present; the clay matrix may have been derived from the feldspar during intense, in-place weathering of the sandstone, which would also

explain the preservation of the angular nature of the quartz. Th presence of heavy elements or refractory minerals was not determined. Some of the sandstone is stained with hematite, whic appears to be in the clay matrix. Some of the sandstone is case-hardened by silica cement; a good example is the bold outcrop on the east side of the aqueduct toward Orestimba Creek.

The main advantages of this deposit for possible mining are its convenient location, its chemical and physical characteristics, and the shallow dip of the strata. Bartow (1984) interpreted this quartz-kaolinite horizon to be about 40 feet thick. Both high-quality quartzose sand and kaolinitic clay coul be extracted from the deposit. Potential uses for the sand could range from industrial applications to container glass, if sufficient reserves could be found.

MRZ-2b$^{i(S2)}$ - South of Cooperstown (Plate 4B): This area is underlain at the surface by sandstone, pebbly sandstone, and conglomerate of the Ione Formation. It has been explored by dril holes 12 and 13 (Plate 11), the logs and cuttings of which were used to classify the area.

The logs of the drill holes reveal a substantial thickness of kaolinitic sandstone that is about 70-80 feet thick. Samples of this material generally consist of fine-grained angular quart with minor potassium feldspar and muscovite, which are largely altered to kaolinite. Small amounts of limonite impart a light buff color to the rock. Dark minerals average about one percent. The matrix is composed of kaolinite, which appears to have developed from in-place weathering of the non-quartz minerals. The kaolinite is a valuable resource in itself, and might be extracted from the sand-sized material as a washed product.

The large thickness of sandstone here suggests that this material may extend for some distance laterally. We have defined the boundary of this area conservatively, however, in recognitio of the marked changes that characterize the depositional environments of the Ione Formation in this region.

MRZ-2b$^{i(S3)}$ - Northwest of La Grange (Plate 4B): This area has characteristics similar to those described above for the area near Cooperstown. It is underlain by the Ione Formation, with some parts overlapped by the Valley Springs Formation. Classification of the area is based on both drill-hole data and on outcrops.

Drill holes 16 and 41 (Plate 11) show substantial thicknesses of kaolinitic sandstone; the thickness in hole 16 is at least 160 feet. X-ray diffraction patterns of samples from these holes show a mineral assemblage of quartz-kaolinite. Color range from cream to pink to rust, depending on the amount of iro oxide present.

Both the uppermost several feet of cuttings in hole 41 and nearby outcrops of sandstone, of perhaps the same horizon, were the cleanest sandstone observed in the Ione Formation within Stanislaus County. Thickness of the horizon in the outcrop was 6-8 feet. The sandstone is white, very friable, medium- to coarse-grained, and has little feldspar. Rock fragments and dark minerals are rare. A grab sample (STS-49, Appendix B) from the outcrop analyzed at about two-thirds quartz to one-third kaolinite. A comparison of X-ray diffraction patterns of this sandstone with a sample from the Poverty Flat Sandstone in the Coast Ranges is presented in Appendix B. This material is another example of that from which by-product kaolinitic clay could also be extracted.

This area is favorable for additional exploration for specialty sand based on outcrops and the drill-hole data. The log from hole CTN-2 (Plate 11) suggests that the Ione may be over 200 feet thick here.

MRZ-3a$^{i(S1)}$ - East Side of Coast Ranges (Plate 4A): This area is generally underlain by the Tesla Formation, which crops out continuously from near Ingram Canyon, southward to the Merced County line. It consists mainly of interbedded very fine- to medium-grained sandstone, pebbly sandstone, and siltstone deposited in a shallow marine environment. To the north, in the Corral Hollow area of San Joaquin County, the Tesla appears to have been deposited in even shallower fluvial-deltaic conditions, similar to the Ione Formation; here, it was mined for quartzose specialty sand, kaolinitic clay, and lignite. In contrast, the area in Stanislaus County, with its deeper environment, was best suited for deposition of sandstone rather than claystone; all outcrops observed were either sandstone or siltstone.

Despite its wide distribution, the Tesla crops out very little; consequently, evaluation of its significance as a source of specialty sand was not possible. Some sandstone horizons are quartz-rich, but the formation as a whole does not appear to have been as intensely weathered as the younger sandstone of the Poverty Flat and Ione. The Tesla tends to have more feldspar, mica, and dark minerals than either of these units. Nonetheless, quartz is by far the dominant mineral present, a characteristic that may make particular sandstone horizons in the Tesla favorable for specialty use. Two horizons in particular, the "A" and "C" sands of Booth (1950) and Collins (1949), which are shown as queried members of the Tesla on Plate 1A, may fall in this category. Locally, these units have iron oxide staining and are case hardened.

Structurally, the dip of the Tesla ranges from moderate to very shallow. Stratigraphic horizons appear to be persistent along strike for miles in some cases, which can result in large tonnages of material associated with specific horizons. The most

favorable areas structurally are those from about Salado Creek south, where the exposed Tesla widens dramatically.

MRZ-3a$^{i(S2)}$ - Tesla Member in Eastern Coast Ranges (Plate 4A): Extending for at least 10 miles is a persistent stratigraphic member of the Tesla Formation shown as Ttq on Plate 1A. Booth (1950) and Collins (1949) referred to this horizon as the "B" sand. We have classified this member as a mineral resource zone separate from the main Tesla because it exhibits properties noteworthy among those of the formation in general.

Of the horizons observed in the Tesla Formation, this member has the most potential as a source of specialty sand. It crops out more extensively than any other horizon in the formation, mainly because of ferruginous zones that form well-indurated crusts over softer interior rock. It generally has a shallow dip to the east and appears to maintain its lithologic character along strike. Its estimated thickness is about 100-200 feet.

Mineralogically, this horizon was the cleanest observed in the Tesla. It consists dominantly of quartz and minor feldspar (estimated as low as 8 percent), with a kaolinitic clay matrix. The silica content of one sample was 90 percent (Appendix B). Quartz is both glassy and frosted. Grains are generally subangular, although rounded and angular grains are present. Dark minerals were estimated at a few percent, and one sample had no observable mica. The clay matrix was probably derived from in-place weathering of feldspar and mica.

Methodical sampling and testing might allow reclassification of this horizon to MRZ-2b. Advantages for mining include potentially large tonnages, lateral continuity, high-quartz content, proximity to transportation routes, and its visual isolation. The extent of ferruginous zones is unknown, but may be a minor component of the entire volume.

MRZ-3a$^{i(S3)}$ - Crow Hill Area (Plate 4A): In the vicinity of Crow Hill, the Poverty Flat Sandstone is exposed in three separate areas both north and south of Crow Creek. Where observed, the formation here is composed of sandstone and conglomerate in an apparently thinner stratigraphic sequence than that south of Orestimba Creek. Sandstone observed here is quartz-rich, but not as clean as the sandstone south of Orestimba Creek. It is not as well-sorted and contains more feldspar, mica, and lithic grains.

MRZ-3a$^{i(S4)}$ - Northwest of Cooperstown (Plate 4B): This area coincides with the area classified as MRZ-2b$^{i(K1)}$ for sedimentary kaolinitic clay. Drill-hole data indicate the presence of sandstone, interpreted to be Ione Formation, at depth. The data are insufficient, however, to determine if the sandstone is a significant deposit for specialty uses.

MRZ-3b$^{i(S1)}$ - Northwest of Cooperstown (Plate 4B): This area coincides with the area classified as MRZ-3a$^{i(K1)}$ for sedimentary kaolinitic clay. Logs of drill holes (Plate 11) do not show sandstone of the Ione Formation in the subsurface, but this information does not preclude its presence between the drill holes.

SPECIALTY SAND AND SEDIMENTARY KAOLINITIC CLAY

MRZ-3a$^{i(S,K1)}$ - South of Orestimba Creek (Plate 4A): A broad area of exposed Poverty Flat Sandstone that lies along and east of the California Aqueduct has potential for both specialty sand and kaolinitic clay. Observations were insufficient, however, to determine if significant deposits of such material are present.

Bartow (1984) determined the thickness of the Poverty Flat here to be about 400 feet. It is composed largely of sandstone, with a 20-foot thick horizon of kaolinitic claystone in its upper part. As a whole, the Poverty Flat records a significant change from deep marine to nonmarine deposition, the latter under tropical conditions as indicated by the patchy iron oxide stains described above for the MRZ-2b area. Similar conditions prevailed for the Ione Formation to the east and are evidence for partial correlation of the two units. The conditions favored development of the quartz-rich sandstone and kaolinitic claystone (residual or sedimentary) recognized in this area, although the lateral continuity of either material was not determined during this study.

SPECIALTY SAND AND DIMENSION STONE

MRZ-3a$^{i(S,St)}$ - Cooperstown-La Grange Area (Plate 4B): The three areas of this group coincide with those classified as MRZ-2a or MRZ-2b for sedimentary kaolinitic clay. Deposits of sandstone of the Ione Formation are present in each area. They may be suitable for either specialty purposes or as dimension stone, depending on the physical and chemical properties of the deposits.

EXPANSIBLE SHALE

MRZ-3a$^{i(Sh1)}$ - Adobe Creek Area (Plate 4A): A large area around Adobe Creek and Copper Mountain is underlain by rocks of the Adobe Flat Shale Member of the Panoche Formation, which also includes rocks mapped by previous workers as Knoxville(?) Formation (Plate 1A). Prevalent among these units are abundant fine-grained sedimentary rocks that may be of sufficient quality for use as expansible shale. Parts of similar formations elsewhere have been used for this purpose as described previously. The lack of test data on samples from these units and

the variability in sediment character (sandstone is present locally) of the strata prevented determination of the significance of the mineral resource here, however.

DIMENSION STONE ONLY

MRZ-3a$^{i(St1)}$ - Southeast of La Grange (Plate 4B): These two areas are underlain by the Merced Falls Slate, which consists mostly of slate and small amounts of metamorphosed sandstone and tuff. Typically, the slate is very dark gray, exhibits excellent cleavage in places, and locally has disseminated cubes of pyrite. The best exposures are seen along the Modesto Irrigation District canal east of La Grange. Many of the structures associated with the nearby La Grange Dam were constructed with this material.

Although not abundantly exposed at the surface, it is probable that good bodies of slate are present throughout these two areas. Such material could be used as dimension stone and perhaps might serve as expansible shale. A disadvantage of the slate is the presence of pyrite, which can oxidize and cause undesirable discoloration.

MRZ-3a$^{i(St)}$ - Cooperstown Area (Plate 4B): In the vicinity of Cooperstown are several small erosional remnants of resistent Ione Formation composed largely of indurated sandstone and conglomerate. They form caps on basement rock of the Foothills Terrane. These areas are likely too small to be considered as important potential sources of kaolinitic clay or specialty sand, but might be sources of dimension stone or decorative rock.

DIMENSION STONE AND EXPANSIBLE SHALE

MRZ-3a$^{i(St,Sh1)}$ - Eastern Coast Ranges (Plate 4A): This zone covers the entire area in the Coast Ranges underlain by both the Panoche Formation and Moreno Formation of the Great Valley Sequence. Both formations are composed mostly of interbedded marine sandstone, shale, and mudstone layers deposited by turbidity currents. The Panoche has more sandstone horizons than the Moreno, which is characterized more by shale and mudstone.

Sandstone of the Panoche is dense and hard in places, whereas sandstone of the Moreno appears to be softer in general. As mentioned above, units that are stratigraphically equivalent to the Panoche have been quarried for dimension stone elsewhere; at these localities, only the harder rock was used. The Panoche and Moreno in Stanislaus County both have rock that is probably of similar quality to these other localities, but detailed sampling and testing is necessary to determine the significance of the deposits.

Shale and mudstone are abundant in both formations and are probably of quality similar to that mined in the San Francisco Bay Area as described previously. A disadvantage of the deposits here is the generally steep dip of the shale horizons as well as their thicknesses, which are commonly small because of interbedded sandstone. Such conditions are less favorable for economic mining. As described above for the Adobe Canyon area, the deposits in both the Panoche and Moreno would require detailed sampling and testing to determine their significance as resources of expansible shale.

INDUSTRIAL MINERALS FOUND IN THE COUNTY BUT NOT CLASSIFIED

Coal

Coal, in the form of lignite, is associated with the Ione Formation. It was observed in several of the exploratory holes drilled in the Cooperstown-La Grange area (Plate 11). Generally, the seams are thin and had a maximum reported thickness of a few feet in holes CTN-5 and CTN-10 at depths of about 400-500 feet. No coal was observed in outcrops of the Ione Formation in the county, however. For many years, the Ione in Amador County has been mined for coal.

Outcrops of coal were reported (Appendix A) in a few places in the foothills of the Coast Ranges. These were not verified in the field, but if legitimate, they are probably associated with the Tesla Formation. A potential disadvantage for mining deposits from the Tesla in this area is the moderate dip of the strata. The Tesla was a major source of coal in the Corral Hollow area of San Joaquin County (Huey, 1948).

Common Clay

Common clay is present throughout the Quaternary alluvium of the Great Valley. Many years ago, it was mined near several communities for the manufacture of bricks.

Mineral Pigment (ochre)

Mineral pigments are natural or synthetic mineral substances used to impart color to manufactured products, such as paints. Yellow and red iron oxides (ochre) are the most commonly used mineral pigments.

Yellow ochre was mined from several properties (Appendix A) in the Ione Formation near Knights Ferry in the early part of the 20th Century for coloring of paints. Outside this small area,

however, ochre of commercial quality was not observed in the Ione Formation.

Olivine

The mineral olivine is used in refractories. The ultramafic rock, dunite, is composed almost entirely of olivine, and if unserpentinized, can be an important source of this mineral.

The most obvious areas in Stanislaus County that might have sources of olivine are those underlain by the dunite-wehrlite unit of the Coast Range Ophiolite. Virtually every observed outcrop of this rock, however, shows some degree of serpentinization. Many samples of dunite were measured by several workers (Saad, 1969; Himmelberg and Coleman, 1968; Evarts, 1978) for degree of serpentinization. The freshest samples showed about 60 percent serpentinization, while the average was 85 percent serpentinization. Consequently, the dunite-wehrlite unit does not appear to be a favorable source of olivine, unless relatively fresh material can be discovered.

Pumice

Pumice, which is used most commonly as an abrasive or as light-weight aggregate, is found locally in the Valley Springs Formation in the Sierra Nevada foothills. Generally, it is present as either thin horizons of reworked lapilli or inclusions of lapilli-sized clasts in tuff beds. No concentrations of economic interest were observed in the county, however.

Zeolite

The zeolites heulandite and laumontite are reported to be present in the Lotta Creek Tuff (Evarts, 1978; Evarts and Schiffman, 1983). They are evidently widespread, but not in sufficient concentration to be of economic interest.

AREAS CLASSIFIED FOR DEPOSITS FORMED BY HYDROTHERMAL PROCESSES

EPITHERMAL MERCURY AND GOLD

MRZ-1^{h} - Central and Eastern County (Plate 6): This area includes all of Stanislaus County just east of the entire length of the Tesla-Ortigalita Fault Zone. It is well-documented (Davis and Bailey, 1966) that epithermal mercury mineralization in the Coast Ranges of California is restricted to areas underlain by the Franciscan Complex, ultramafic rocks, and parts of the Great

Valley Sequence adjacent to major fault zones, such as the Tesla-Ortigalita and Coast Range. Consequently, we do not expect any significant deposits of mercury and gold formed by hydrothermal activity under epithermal conditions to be present in this area.

MRZ-3a$^{h(M1)}$ - North of Deer Park (Plate 6): This area is defined mainly by the presence of two mercury properties, the Crocker-Winship (19) and Newhall (20). Neither property was visited during this study, but past reports indicate that mercury mineralization, in the form of cinnabar, is common in the area. Locations of the properties are from Maddock (1964), and are assumed here to be accurate. Associated host rocks are apparently graywacke sandstone, greenstone, and serpentinite within the Eylar Mountain Terrane of the Franciscan Complex. Evidently no serious development of these properties was ever accomplished.

The boundary of the area is arbitrary and may not truly reflect the limit of actual epithermal mineralization, which may be more or less extensive than that shown on the map. Nevertheless, the area is probably a fair indication of where epithermal mineralization including mercury and perhaps gold may be present relative to the surrounding region.

MRZ-3a$^{h(M2)}$ - Phoenix Mine (Plate 6): Situated adjacent to the county line in the headwaters region of Del Puerto Creek, this area includes what is probably the most productive mercury mine in the county, the Phoenix (36). Here, mercury in the form of cinnabar was produced from along faults in both hydrothermally-altered graywacke sandstone of the Franciscan Complex and silica-carbonate rock, derived from serpentinite. Production has been estimated at about 200 flasks, with unknown reserves.

This area also includes other areas of mercury mineralization, particularly along the summit area south and east of the Phoenix. One sample analyzed (STC-103, Appendix B) contained fair amounts of mercury, but no gold was detected. The host rock is Franciscan graywacke, which exhibits argillic, silicic, and limonitic-hematitic alteration.

MRZ-3a$^{h(M3)}$ - Adobe Valley Mine (Plate 6): This area encompasses less than two square miles around Adobe Canyon and includes the Adobe Valley Mine (68-69), a mercury property active at least until the early 1940s. This mine is associated with an extensive area of Adobe Flat Shale that exhibits pervasive argillic and limonitic-hematitic hydrothermal alteration. At the mine itself, cinnabar is present as impregnations and fracture-coatings in the altered fine-grained sandstone and shale of the Adobe Flat Shale. The main mineralization is along faults. Past production and reserves at this mine are unknown.

Dumps at this now-sealed mine also show abundant sulfide mineralization other than cinnabar. More importantly, both fire-

assay and ICP chemical analyses (Appendix B) revealed the presence of low-grade gold in cinnabar-impregnated samples. At 0.047 ounces/ton, this mineralization suggests a deposit that might exceed cut-off grades for mining, depending on the tonnage present. Also present are elevated concentrations of copper, zinc, and silver relative to other epithermal deposits observed elsewhere in the county. This mineralization, which is unique among samples collected from epithermal areas in the county, may owe its character to its host rock, the Adobe Flat Shale. This rock unit has abundant dark mudstone and shale, which may have been a source of the base and precious metals.

Similar to the Deer Park area described above, the boundary of the area is arbitrary and may not truly reflect the limit of actual epithermal mineralization, which may be more or less extensive than that shown on the map. The area also includes the known area of hydrothermal alteration around the Adobe Valley Mine and a prospect (66) in hydrothermally-altered gabbro(?). We believe the area is probably a fair indication of where epithermal mineralization, composed of mercury and perhaps gold, may be present relative to the surrounding region.

MRZ-3a$^{h(M4)}$ - Winegar Prospect (Plate 6): This area is defined mainly by the presence of the Winegar Prospect (71), a small property that apparently has had little or no production; reserves are unknown. Here, mercury in the form of cinnabar is present in faulted graywacke sandstone of the Franciscan Complex. The mineralized fault trends approximately west-northwest subparallel to the Coast Range Fault, which is just north of the prospect (Plate 1A).

Because the Winegar Prospect was not visited during this study, we have drawn the boundary of the area in an arbitrary way. The elliptical form of the boundary is meant to reflect the west-northwest trend of mineralization associated with faulting. The boundary may not truly reflect the actual limit of epithermal mineralization, however, which may be more or less extensive than that shown on the map. Nevertheless, the area is probably a fair indication of where epithermal mineralization, composed of mercury and perhaps gold, may be present relative to the surrounding region.

MRZ-3a$^{h(M5)}$ - South Fork of Orestimba Creek (Plate 6): This area covers many square miles in the southwesternmost part of the County, much of which is part of Henry W. Coe State Park. Besides the presence of the Orestimba Mine (79), International Mine (80), and probably several other undocumented mercury properties, this area is noteworthy because of its widespread, pervasive hydrothermal alteration. The boundary of the area approximates the known limits of the hydrothermal alteration.

The alteration is weak to locally intense and consists of the argillic, silicic, and limonitic-hematitic types. Soils developed on altered rocks typically have a pale pinkish cast, which is distinct from that of soils on unaltered rock. Chemical analyses (Appendix B) of several samples of hydrothermally-altered rock from this area did not show any detectable gold, but did show elevated concentrations of mercury.

Clark Blake (U.S. Geological Survey, personal communication, 1992) has mapped many individual linear zones of alteration in this area, which he believes may coincide with faults in the Franciscan Complex and serpentinite bodies. Soliman (1965) noted similar alteration in Franciscan rocks just to the west in Santa Clara County and concluded that the alteration might be as young as Quaternary. Absolute ages of the alteration are still largely unknown, however, and await additional study. Relative to this question are the several local exposures of volcanic dikes (Plate 1A) interpreted by Morrell (1978) to be Tertiary in age. These are the only ones known in the southwestern part of the county, and it may not be coincidence that they are found in a large area of hydrothermally-altered rock. In other words, the igneous activity that generated these bodies may also have driven the hydrothermal alteration and associated mineralization that pervade this area. Consequently, we believe this area is favorable for additional undiscovered deposits of mercury and possibly gold.

MRZ-3b$^{h(M1)}$ - Western Coast Ranges (Plate 6): This large area comprises a region underlain by Franciscan Complex and Coast Range Ophiolite as well as rocks of the Great Valley Sequence adjacent to the Tesla-Ortigalita Fault Zone and related faults. As described above, areas underlain by such rocks and structures are hosts to extensive epithermal mineralization throughout the Coast Ranges of California. This mineralization is dominantly mercury, but some gold is present locally (Albers, 1981).

With a few minor exceptions (small showings at the Liberty Mine and Grummett Mine), this area is not known to contain epithermal deposits. The geologic environment is very favorable, however, for the presence of such deposits. In particular, areas within a mile of both the Tesla-Ortigalita and Coast Range Faults are good sites for prospecting as they are major structures that could have served as conduits for the upward movement of metal-bearing hydrothermal fluids. A typical host material for mercury mineralization, silica-carbonate rock, was observed by Maddock (1955) at several sites along the northern Tesla-Ortigalita. Areas with Adobe Flat Shale may also be favorable prospecting areas for low-grade epithermal gold.

MESOTHERMAL GOLD AND SILVER

MRZ-1^{v,h} - Central and Western County (Plate 7): This area consists of all of Stanislaus County except for a narrow strip along the northeast edge. There is little likelihood of any significant deposits of gold and silver formed by hydrothermal activity under mesothermal conditions in this area. Such deposits are associated with quartz veins in the Jurassic island-arc terrane to the east. Cenozoic sediments cover this terrane to progressively greater depths to the west, however, which makes economic mining of any concealed deposits impractical.

In the Coast Ranges, rocks of both the Franciscan Complex and Coast Range Ophiolite are cut locally by quartz veins, such as at the Hammond Mine (77). Although a few of those observed in the ophiolitic rock contained sparse sulfide mineralization, no significant mineral deposit of this class has ever been identified in either of these geologic units anywhere in the Coast Ranges of California. Consequently, we conclude there is little likelihood of any such deposits in southwestern Stanislaus County.

MRZ-3b$^{h(G1)}$ - Sierra Nevada Foothills (Plate 7): These areas are underlain almost entirely by exposed metamorphic and plutonic rock of the Jurassic Foothills Terrane. In many places, the rock is cut by younger Mesozoic quartz veins with characteristics similar to those of the famous Mother Lode belt farther east. The quartz veins in the Mother Lode, with both fissure-filling and replacement-type features, have been a world-class source of gold and silver.

Deposits of gold and silver are not known to be present in any of the quartz veins of the Sierra Nevada foothills within the county; quartz veins observed had little or no sulfide mineralization. Nonetheless, the veins themselves and country rock immediately adjacent to them are a favorable geologic environment for such deposits.

MRZ-3b$^{h(G2)}$ - Sierra Nevada Foothills (Plate 7): This area is adjacent to the exposed Foothills Terrane in the Sierra Nevada foothills. Here, we estimate the depth to the top of the terrane, which is covered by younger sedimentary and volcanic rocks, to be no more than 500 +/- 200 feet. This figure represents a conservative depth limit for economic removal of overburden during mining and is based on both drill-hole information and projection of a shallow-dipping, flat planar surface that represents an ideal uneroded top of the basement. The error allows for the eroded character of the basement surface as well as variation in the present-day topography.

As indicated by drill holes, geologic projection, and aeromagnetic data, we expect the concealed basement to consist of

Foothills Terrane similar to that exposed to the east in MRZ-3b$^{h(G1)}$. This terrane is geologically favorable for the presence of quartz veins and associated deposits of gold and silver.

AREAS CLASSIFIED FOR DEPOSITS FORMED BY MAGMATIC SEGREGATION

MRZ-1^{v,s} - Central and Eastern County (Plate 5): Most of Stanislaus County falls in this area, including the Sierra Nevada foothills, the Great Valley, and the eastern part of the Coast Ranges. The host rocks for chromite deposits formed by magmatic segregation are variably serpentinized ultramafic bodies, which are not known or expected to be present in this area at shallow depths. Furthermore, the aeromagnetic data (Plate 10; Appendix C) for this area do not reveal any positive anomalies of the type associated with the ultramafic bodies in the western part of the county. The positive anomaly under Modesto is far too deep and of inconclusive origin to consider as a possible site of chromite deposits.

MRZ-3a$^{m(C1)}$ - Chrome Camp Mine (Plate 5): This small area is classified based on characteristics associated with the Chrome Camp Mine (35), one of the most productive chromite properties in the county. Here, chromite was mined from a wide shear zone that separates the harzburgite unit of the Coast Range Ophiolite from Franciscan Complex. It is not clear from descriptions whether the host rock for the chromite is harzburgite or a small body of dunite within the harzburgite unit. This property was not visited, and the location reported in various references is in disagreement.

MRZ-3a$^{m(C2)}$ - Adobe Canyon and Hideout Canyon (Plate 5): This area includes the most important known chromite deposits in Stanislaus County. It coincides approximately with the largest exposure of the dunite-wehrlite unit of the Coast Range Ophiolite, which is acknowledged as the dominant host rock of the chromite deposits (Evarts, 1978). Within this area are three of the largest producing mines, the No. 5 (51-55), Black Bart (28), and Adobe Canyon (63-64), in addition to numerous prospects. There are no known obvious massive ore bodies exposed at the surface, but small bands and layers of disseminated chromite can be observed in many places throughout the area. Known reserves are estimated to be at least 1,500 tons (Hawkes and others, 1942).

According to Evarts (1978), nearly all of the larger massive, or podiform, bodies of chromite are found in zones of highly sheared dunite in this area. Typically, because of their resistance to ductile deformation, the massive bodies controlled and determined sites of faulting and shearing in the dunite-wehrlite unit. Of particular note is that part of the area that includes the No. 5 Mine and Adobe Canyon Mine. Evarts (1978)

concluded that nearly all of the known larger massive bodies were concentrated in this part. This subarea is thus especially favorable for finding additional ore bodies at depth along shear planes; exploration techniques such as that described by Grivas and others (1993) for locating and drilling blind ore bodies may be useful here.

MRZ-3a$^{m(C3)}$ - Peach Tree Creek (Plate 5): Situated along and subparallel to Peach Tree Creek, these areas approximately coincide with a narrow, west-northwest-trending group of exposures of the important dunite-wehrlite unit of the Coast Range Ophiolite. Associated with these areas are the Lucky Girl Mine (45) and Black Bear Mine (49), each of which apparently produced less than 500 tons of ore. Mainly because of their small size, these areas are not expected to have as much potential as the Hideout Canyon-Adobe Canyon area described above. Nonetheless, the presence of the same host rock here is evidence of a good geologic environment for the potential discovery of blind ore bodies at depth.

MRZ-3b$^{m(C1)}$ - Headwaters of Del Puerto Creek (Plate 5): Included here are the several areas that are underlain by the harzburgite unit of the Del Puerto Ophiolite, as mapped by Evarts (1978). In general, the harzburgite itself has ubiquitous disseminated chromite, but only in very small amounts (Evarts, 1978). Within the harzburgite unit, however, are several bodies of dunite (Plate 1A), which are chemically distinct from those that comprise the more extensive dunite-wehrlite unit. Evarts (1978) observed that these dunite bodies contain both disseminated chromite as well as massive chromite in small podiform deposits. One example is a prospect (27) in Hideout Canyon. More bodies of this type of dunite may be present than are shown on the geologic map (Plate 1A).

None of the dunite bodies were observed during the present study because of accessibility, yet the observations by Evarts (1978) indicate that areas underlain by the harzburgite unit are a favorable geologic environment for the presence of chromite deposits. The most favorable localities for exploration are those underlain by the dunite masses and also along the major fault contacts with the adjacent Franciscan Complex. An example of the latter is the Chrome Camp deposit described above.

MRZ-3b$^{m(C2)}$ - Quinto Creek Ophiolite Remnant (Plate 5): This area covers a long northwest-trending strip of serpentinite thought to be a remnant of the Coast Range Ophiolite. Despite the large amount of serpentinization, masses of less-altered harzburgite and dunite are still recognizable in this area (Bailey and others, 1970; Hopson and others, 1981). Within the harzburgite, we found minor amounts of disseminated chromite. These observations indicate a favorable geologic environment for the presence of chromite deposits.

MRZ-3b$^{m(C)}$ - Western Coast Ranges (Plate 5): Included here are numerous areas that are underlain by known or suspected bodies of serpentinized ultramafic rock. Commonly, the areas are either within or along the boundaries of rocks mapped as Franciscan Complex. Typically, the contacts with adjacent rocks are faults. Some of the bodies may be remnants of Coast Range Ophiolite, whereas others may be tectonic blocks within the Franciscan. An example of the latter is the small mass of chromite-bearing serpentinite at the Grummett Mine (11). Otherwise, there are no known deposits of chromite present in these areas.

Several of the areas do not have serpentinite mapped at the surface, but positive aeromagnetic anomalies (Plate 10) indicate that serpentinite is probably present at depth; exposed bodies are strongly magnetic and no other rocks in this region are known to exhibit strong magnetic properties. Consequently, these areas, along with those underlain by known serpentinite, are favorable geologic environments for the presence of associated chromite deposits. Whether the concealed bodies are at economic depths for mining can only be determined through additional study, including drilling.

AREAS CLASSIFIED FOR DEPOSITS FORMED BY VOLCANOGENIC PROCESSES

MRZ-1^{v,h} - Central and Western County (Plate 7): This area consists of all of Stanislaus County except for a narrow strip along the northeast edge. We conclude there is little likelihood that any significant deposits of base or precious metals formed by volcanogenic processes will be found at economic depths within this area. Such deposits are associated with volcanic rocks of the Jurassic island-arc terrane exposed east of this area. To the west, in the Great Valley, however, Cenozoic sediments cover this terrane to progressively greater depths, which makes economic mining of any concealed deposits impractical.

In the Coast Ranges, the Volcanic Member of the Coast Range Ophiolite and the Franciscan Complex both have submarine volcanic rocks, but each has unique characteristics that suggest little likelihood of finding significant deposits of base and precious metals where these rocks are present in Stanislaus County. For example, only one significant volcanogenic massive sulfide deposit has been discovered in the entire Franciscan Complex of California. This deposit, the Island Mountain in Trinity County, is associated with graywacke in the Central Belt of the Franciscan Complex and is an unusual, isolated occurrence of a sulfide deposit in a subduction complex (Koski and others, 1993). Furthermore, all of the Franciscan Complex in Stanislaus County is mapped as part of the Eastern (Yolla Bolly) Belt (Bennison and others, 1991), which is a different geologic unit of the entire subduction complex.

Regarding the origin of the basalt (greenstone) in the Franciscan Complex and its possible association with volcanogenic deposits, Cloos (1990) concluded that Franciscan pillow basalt northwest of San Francisco Bay probably formed in submarine seamounts, which are a less favorable environment for genesis of sulfide deposits than is a submarine spreading center with its abundance of thermal springs ("black smokers"). The basalt was then incorporated as fragments into the accretionary prism when the seamount was scraped off the descending oceanic plate during subduction. The blocks of greenstone in the Franciscan of Stanislaus County may also be fragments of seamount, although too little is known about the rocks to verify this hypothesis. Of note is Maddock's (1955) observation of small clusters of anhedral pyrite in only two sections of greenstone in the Del Puerto region of the county.

The volcanic and plutonic rocks of the Coast Range Ophiolite in California might, at first glance, appear to be an ideal environment to find deposits of massive sulfides. Elsewhere in the world, ophiolitic rocks are hosts to major deposits of base metals. Within the Coast Range Ophiolite, however, little or no sulfide mineralization has been recognized (Schiffman and others, 1991; Robertson, 1989). In the San Francisco Bay Area, massive pyrite and minor copper and zinc sulfides were once mined from the Leona Rhyolite, which may actually be a quartz keratophyre (Albers, 1981). It is not clear, however, if this unit is part of the Coast Range Ophiolite or Franciscan Complex. In a study of the southern Coast Ranges, Robertson (1989) observed minor hydrothermal mineralization at only two localities, one in the Del Puerto Ophiolite and the other in the ophiolite remnant along Quinto Creek.

Locally, in a detailed study of the Del Puerto Ophiolite, Evarts and Schiffman (1983) recognized traces of pyrite in less than 10 percent of samples collected from the Volcanic Member and less than 40 percent of samples collected from the Plutonic Member. They concluded that there may have been too much oxygen in the hydrothermal fluids to allow formation of massive-sulfide deposits in the Del Puerto Ophiolite. In the vicinity of Copper Mountain, a prospect for copper was reported (Appendix A), but this locality was not verified in the field. Schiffman and others (1991) concluded that the absence of massive-sulfide deposits in the Coast Range Ophiolite in general may reflect a fundamental difference in the nature of hydrothermal discharge in the Coast Range Ophiolite compared to other ophiolites.

MRZ-3a$^{V(BP1)}$ - Sierra Nevada Foothills (Plate 7): These areas are underlain by exposed metamorphic and plutonic rock of the Gopher Ridge Volcanics. They are part of an island-arc terrane, which, just to the east across the county line, has been mined in several places (Plate 8C) for massive and disseminated sulfide

deposits that contain both base metals (copper, zinc, lead) and precious metals (gold and silver). These deposits are within hydrothermally-altered felsic volcanic rocks, which Albers (1981) reported to be quartz keratopyhre; alteration consists mainly of sericitization and silicification and was completed before the regional greenschist-facies metamorphism of the Nevadan Orogeny. Similar rocks are exposed in Stanislaus County from State Route 4, south to Cardoza Ridge near La Grange.

Reconnaissance of the Gopher Ridge Volcanics in the field revealed many zones of disseminated pyrite and local areas of metamorphosed hydrothermally-altered volcanic rock. Alteration observed was both silicic and sericitic. Chemical analysis (Appendix B) of a few samples from these areas showed elevated concentrations of copper, zinc, and silver, but no gold. These observations and the nearby presence of mined deposits of massive sulfides are evidence that potentially important deposits of massive sulfides may be present in Stanislaus County.

MRZ-3b$^{v(BP)}$ - Sierra Nevada Foothills (Plate 7): This area is adjacent to the exposed island-arc Foothills Terrane described above. Here, we estimate the depth to the top of the terrane, which is covered by younger sedimentary and volcanic rocks, to be no more than 500 +/- 200 feet. This figure represents a conservative depth limit for economic removal of overburden during mining and is based on both drill-hole information and projection of a shallow-dipping, flat planar surface that represents an ideal uneroded top of the basement. The error allows for the eroded character of the basement surface as well as variation in the present-day topography.

As indicated by drill holes, geologic projection, and aeromagnetic data, we expect the basement to consist of Foothills Terrane similar to that exposed to the east. In places, however, rocks of the Merced Falls Slate may be present in the subsurface; such rocks are not known to be hosts to syngenetic massive sulfide deposits. An example of such a place may be the site of the residual gravity trough at Cooperstown, shown on Plate 11. Nevertheless, the subsurface of this area is geologically favorable for the presence of deposits of base and precious metals associated with volcanogenic massive sulfides. Sites of positive aeromagnetic anomalies may be particularly favorable sites for prospecting as described above.

AREAS CLASSIFIED FOR DEPOSITS FORMED BY VOLCANOGENIC-SEDIMENTARY PROCESSES

MRZ-1^{v,s} - Central and Eastern County (Plate 5): The entire area of Stanislaus County east of the area underlain by the Franciscan Complex and bounded by the Tesla-Ortigalita Fault Zone is not

expected to have any significant deposits of manganese formed by volcanogenic-sedimentary processes as described above. This type of deposit is restricted to the Franciscan Complex, with the exception of a low-grade deposit associated with the Lotta Creek Tuff near Del Puerto Canyon.

MRZ-3a$^{v(M1)}$ - Mount Oso (Plate 5): This area covers the most important known manganese deposits in Stanislaus County. Part of the famous Ladd-Buckeye District, these deposits have contributed substantially to this district's reputation as the most productive in California.

Within the area are the three most productive mines in the county, including the Buckeye (4,5), Liberty (1), and Tip Top (7). Cumulative production from the three is estimated at more than 30,000 tons of ore, most of which was from the Buckeye (Trengove, 1960). Also in the area are many other mines and prospects, which are listed in Appendix A; some of these are not shown on Plate 8A because their reported locations are ambiguous and they were not found in the field.

This area is largely underlain by rocks mapped as Franciscan Complex. Raymond (1973a) subdivided the complex into several broken formations of coherent strata and melange units, which are shown on Plate 1A. The units covered by the area include all of the Grummett and Oso Broken Formations and most of the Blind Man's Broken Formation. It also includes all of the Moran Zone of the Falcon Formation and part of the Rocky Point Melange. Of note regarding these units is the remarkable assemblage of massive and thin-bedded chert within them; many of the larger masses have been shown separately on Plate 1A. Such a substantial concentration of chert is not known anywhere else in the Franciscan Complex. These chert bodies are the sites of the syngenetic interbedded manganiferous sediments that were mined as low- and high-grade manganese ore.

Of all the units, the Grummett has the highest percentage of chert, and is also host of the ore at the Buckeye Mine. This unit has the most potential of any for discovery of new ore bodies, some of which may prove to be significant. The main advantage of the unit, besides the abundance of chert, is the relative lateral stratigraphic continuity of the chert horizons. In other units, particularly the melange type, the chert horizons are commonly dismembered and thus of small size. Correspondingly, any interbedded manganese deposits have limited lateral continuity.

The character and history of emplacement of the Franciscan rocks here, and elsewhere in the county for that matter, indicate that there are undiscovered, concealed manganese deposits at depth. Those exposed at the surface have been largely mined out or are of insufficient grade at present to make them economic now or in the near future. Nonetheless, because of the geologic

characteristics and mining history cited above, this area represents that part of Stanislaus County with the most potential for the discovery of additional manganese deposits.

MRZ-3a$^{v(M2)}$ - North of Del Puerto Canyon (Plate 5): This small east-west-trending area is between ultramafic bodies of the Coast Range Ophiolite. Mapped as part of the undifferentiated Eylar Mountain Terrane of the Franciscan Complex, the area contains a few small manganese prospects (32-34) within chert horizons. This area is favorable for the discovery of additional deposits because of the character of the Franciscan Complex. The chert bodies are not as extensive here, however, as in the Mount Oso area described above.

MRZ-3a$^{v(M3)}$ - Summit Area South of Del Puerto Canyon (Plate 5): This area is part of the Black Wonder District, which extends into adjacent Santa Clara County. Several thousand tons of manganese ore were mined from this district, most of which was from the Santa Clara side.

Several mines and prospects (37,38,40,42,70) are within this area. In addition, one of the most productive mines, the Jones, is just across the county line. All are in manganese bodies interbedded with massive and thin-bedded chert of the undifferentiated Eylar Mountain Terrane of the Franciscan Complex. Masses of chert are common in this area and are expected to contain additional concealed ore bodies at depth.

MRZ-3a$^{v(M4)}$ - Central Del Puerto Canyon (Plate 5): This small area is notable because it contains the only known occurrence of manganiferous sediment in rocks other than the Franciscan Complex. Deposited here between the Lotta Creek Tuff and the underlying Volcanic Member of the Coast Range Ophiolite are iron- and manganese-rich sediments, interpreted by Robertson (1989) to be of submarine volcanogenic origin. Exposed laterally for a few hundred feet, these sediments are associated with tuffaceous radiolarian chert. The manganese is present both as minor lenses in the chert itself and on top of the chert as a small bed of oxides no more than about 1 foot thick. The extent of this mineralization down dip and along strike beyond the outcrop area is unknown. The outcrop area has been explored by a small prospect, thought to be the Hammond (73).

MRZ-3b$^{v(M1)}$ - North of Mount Oso (Plate 5): Situated adjacent to the region that contains both the Buckeye Mine and Liberty Mine, this area is underlain by the Sulfur Gulch Broken Formation and the Falcon Formation, both of the Franciscan Complex. There are no known deposits of manganese within these units.

The Sulfur Gulch consists mostly of graywacke with minor chert, whereas the Falcon is composed largely of chert (Raymond, 1973a). Of the two, the Falcon has a much greater potential for

the discovery of manganese deposits because of its high volume of chert.

MRZ-3b$^{v(M2)}$ - North of Del Puerto Canyon (Plate 5): This large area covers the region north of Del Puerto Canyon that is adjacent to the Mount Oso area classified as MRZ-3a. The area is underlain mainly by undifferentiated Eylar Mountain Terrane and melange units of the Franciscan Complex. Except for the minor lenses at the Magnesia Camp Prospect (74), there are no known deposits of manganese within this area. Manganese stains and coatings on rock surfaces are visible in many places, however.

Much of Franciscan Complex here consists of melange with tectonic blocks of chert. Good examples are visible along Del Puerto Canyon Road, just north of the Magnesia Camp Prospect. Maddock (1955) reported abundant chert associated with the greenstone in Washington, Arkansas, and Deer Park Canyons. Because of the relatively small size of these chert bodies, however, compared to those in the coherent strata around Mount Oso, it is much less likely that large deposits of manganese will be discovered here.

MRZ-3b$^{v(M3)}$ - Southwestern Coast Ranges (Plate 5): Situated in the southwesternmost part of the county, this extensive area is underlain by both undifferentiated Eylar Mountain Terrane and undifferentiated Burnt Hills Terrane of the Franciscan Complex. Although stains and coatings of manganese oxides can be found in places, there are no known deposits anywhere in the area.

Much of the Eylar Mountain Terrane here is melange, with uncommon tectonic blocks of chert (Cowan, 1974; Clark Blake, U.S. Geological Survey, personal communication, 1992). That part of the Eylar Mountain Terrane adjacent to the Black Wonder District (MRZ-3a$^{i(M3)}$) may have more chert than that farther south.

The area underlain by the Burnt Hills Terrane appears to have more and larger chert horizons than the Eylar Mountain. Notable among these is the thin-bedded chert of the Rooster Comb, along the South Fork of Orestimba Creek. To the west are other prominent outcrops of resistant chert sequences within the Burnt Hills Terrane.

The presence of bodies of chert within the Franciscan Complex in this area indicates a favorable geologic environment for the presence of manganese deposits within the chert. Overall, however, this area is not expected to have as high a potential for the presence of manganese deposits as that part of the county from the Black Wonder District northward.

MRZ-3b$^{v(M4)}$ - West of Copper Mountain (Plate 5): These two areas cover southeast extensions of the same geologic environment observed at the Hammond(?) Prospect described above. Here, the

Lotta Creek Tuff is generally in depositional contact with the underlying Volcanic Member of the Coast Range Ophiolite; locally, the contact is faulted. Although not observed in the field, the contact zones of the two areas may be the site of manganiferous sediments similar to those at the Hammond exposure to the northwest. No manganese mineralization has been reported in either area, however. The dip of the strata in this region is moderate (Evarts, 1978) and concealed manganese mineralization could be present down dip to the west of the exposed contact zone.

OTHER COMMODITIES NOT CLASSIFIED

ASBESTOS AND TALC

Asbestos and talc are commonly found in serpentinized ultramafic rock, such as that exposed in southwestern Stanislaus County. Although minor amounts of both were detected by X-ray diffraction during this study, there is no known indication of any commercial quantities in the serpentinite bodies of the county. These remain, however, favorable geologic environments for the presence of asbestos and talc.

GOLD, SILVER, AND PLATINUM (placer)

For many years, placer gold was one of the main mineral commodities produced in Stanislaus County. Extraction was largely by dredging of Holocene and Modesto Formation sediments along the Tuolumne and Stanislaus Rivers (Appendix A); silver and platinum-group elements (Sjoberg and Gomes, 1981) were also extracted as by-products. Several hydraulic operations mined gold from older Cenozoic sediments, including the Laguna and Ione Formations. Because of their largely volcanic nature, neither the Valley Springs nor Mehrten Formations have been important producers of gold in the county.

Concentrations of gold, silver, and platinum are not expected to be in high-enough placer concentrations in the county to warrant full-scale mining solely for those commodities, either now or in the near future. Furthermore, society today will likely not tolerate the disturbance of hundreds of acres of ground, especially along rivers, for mining of gold by itself. Alternatively, gold has been extracted for many years as a by-product of aggregate mining along the rivers of the county, and this activity is expected to continue. For these reasons, we have not classified land in Stanislaus County for these placer commodities.

NICKEL AND COBALT

Nickel and cobalt, which generally have elevated concentrations in ultramafic rocks, are rarely concentrated sufficiently to form commercial ore bodies. Typically, these are in the form of primary sulfide deposits or secondary lateritic deposits.

In Stanislaus County, none of the ultramafic rocks are known to have enriched concentrations of nickel or cobalt in the bedrock. Regarding laterites, the climate of this region has probably been arid for too long to have formed any commercial concentration of these metals above the host ultramafic rocks.

PART V

AGGREGATE RESOURCE AREAS IN STANISLAUS COUNTY

PART V - AGGREGATE RESOURCE AREAS IN STANISLAUS COUNTY

Aggregate Resource Areas in Stanislaus County are identified on six inset maps on Plate 3 (Inset Maps A-F). The relationship between areas classified MRZ-2a$^{sg(C)}$ and MRZ-2b$^{sg(C)}$ in this report and the resulting Aggregate Resource Areas are described here. Aggregate Resource Areas have been numbered generally from west to east and from north to south. The Aggregate Resource Areas and their respective category of significance are summarized in Table 6.

OVERVIEW OF THE AGGREGATE CLASSIFICATION PROCESS

The Division of Mines and Geology is responsible under SMARA for carrying out the classification phase of the classification-designation process. Classification entails six distinct but interrelated steps. These six steps are described below.

1. Determination of Study Area. Stanislaus County was chosen for study by the State Mining and Geology Board.

2. Establishment of Mineral Resource Zones (MRZ). All lands within Stanislaus County are assigned Mineral Resource Zone classifications (MRZ-1, MRZ-2a, MRZ-2b, MRZ-3a, or MRZ-4, which are defined in Part II of this report, "California Mineral Land Classification System") based on a geologic appraisal of concrete-grade aggregate resource potential. This mineral land classification is presented on Plates 2A, 2B, and 2C, and was described in previous sections of this report.

3. Identification of Aggregate Resource Areas. Lands known to contain significant deposits of concrete-grade aggregate resources (areas classified as MRZ-2a or MRZ-2b in Step 2) are evaluated to determine whether or not current uses of these lands preclude possible future mining. Areas currently permitted for mining and areas found to have land uses compatible with possible future mining are considered available for mining. MRZ-2a and MRZ-2b areas that are not yet developed, but which have Specific Plans approved by local governments, were not considered to be available for mining. Aggregate Resource Areas that identify land available for mining are delineated on Plate 3 and described in this part of the report.

4. Calculation of Resource Tonnages within Aggregate Resource Areas. Investigation of on-site conditions, measurements of the areal and vertical extent of aggregate deposits, subsurface drill-hole information, waste-material percentages, and deposit densities are used to calculate tonnages of concrete-grade aggregate reserves (deposits in land owned by aggregate producers and permitted for mining by the local government as of January 1, 1993) and resources (all deposits of concrete-grade aggregate,

Table 6. Aggregate Resource Areas identified on Plate 3.

ARA #	CATEGORY*	ARA AREA	GEOGRAPHIC LOCALITY	ACTIVE AGGREGATE QUARRY NAME AND OPERATOR**
ARA-1	(S)	12 acres	Hospital Creek Fan	
ARA-2	S	48 acres	Hospital Creek Fan	
ARA-3	HS	561 acres	Hospital Creek Fan	
ARA-4	(S)	6 acres	Hospital Creek Fan	
ARA-5	S	192 acres	Orestimba Creek Fan	
ARA-6	IS	107 acres	Orestimba Creek Fan	Orestimba Pit - Frank B. Marks & Son, Inc.
ARA-7	(S)	30 acres	Orestimba Creek Fan	
ARA-8	(S)	134 acres	Orestimba Creek Fan	
ARA-9	(S)	72 acres	Orestimba Creek Fan	
ARA-10	(S)	20 acres	Orestimba Creek Fan	
ARA-11	(S)	7 acres	Orestimba Creek Fan	
ARA-12	IS	735 acres	Orestimba Creek Fan	Stuhr Road Pit - Frank B. Marks & Son, Inc
ARA-13	S	177 acres	Orestimba Creek Fan	
ARA-14	S	223 acres	Orestimba Creek Fan	
ARA-15	(S)	9 acres	Orestimba Creek Fan	
ARA-16	(S)	8 acres	Orestimba Creek Fan	
ARA-17	(S)	11 acres	Orestimba Creek Fan	
ARA-18	(S)	21 acres	Garzas Creek Fan	
ARA-19	IS	25 acres	Garzas Creek Fan	Garzas Creek Pit - County of Merced Depart of Roads
ARA-20	S	110 acres	Garzas Creek Fan	
ARA-21	(S)	39 acres	Garzas Creek Fan	
ARA-22	HS	832 acres	Calaveras River Terrace	
ARA-23	IS	880 acres	Stanislaus River Channel and Terrace	Munn & Perkins Pit - George Reed, Inc.
ARA-24	(S)	7 acres	Stanislaus River Terrace	
ARA-25	(S)	16 acres	Stanislaus River Terrace	
ARA-26	IS	2,492 acres	Stanislaus River Channel and Terraces	Riverbank Pit - George Reed, Inc.
ARA-27	S	108 acres	Stanislaus River Channel and Terraces	
ARA-28	S	186 acres	Stanislaus River Channel and Terraces	
ARA-29	S	66 acres	Stanislaus River Channel and Terraces	
ARA-30	S	309 acres	Stanislaus River Channel and Terrace	
ARA-31	(S)	113 acres	Stanislaus River Channel and Terraces	
ARA-32	(S)	13 acres	Stanislaus River Terrace	

Table 6. Aggregate Resource Areas identified on Plate 3.

ARA #	CATEGORY*	ARA AREA	GEOGRAPHIC LOCALITY	ACTIVE AGGREGATE QUARRY NAME AND OPERATOR**
ARA-33	(S)	28 acres	Stanislaus River Terrace	
ARA-34	(S)	79 acres	Stanislaus River Terrace	
ARA-35	(S)	52 acres	Stanislaus River Terrace	
ARA-36	IS	30 acres	Stanislaus River Terrace	Ardis Pit - George Reed, Inc.
ARA-37	IS	88 acres	Stanislaus River Terrace	Hodge Ranch Pit - George Reed, Inc.
ARA-38	HS	544 acres	Stanislaus River Channel and Terraces	
ARA-39	IS	47 acres	Stanislaus River Terraces	Willms Ranch Pit - Ohe Sand & Gravel
ARA-40	(S)	25 acres	Stanislaus River Terraces	
ARA-41	S	87 acres	Stanislaus River Terraces	
ARA-42	(S)	18 acres	Tuolumne River Terrace	
ARA-43	IS	22 acres	Tuolumne River Terrace	Schmidt Pit - Western Stone Products, Inc.
ARA-44	S	57 acres	Tuolumne River Terrace	
ARA-45	IS	12 acres	Tuolumne River Terrace	Landmark Pit - Western Stone Products, Inc.
ARA-46	IS	995 acres	Tuolumne River Channel and Terraces	Warner Pit and Hickman Pit - Western Stone Products, Inc.
ARA-47	IS	1,165 acres	Tuolumne River Channel and Terraces	Waterford Site - George Reed, Inc.; Waterford Pit (western part) - M.J. Ruddy & Son, Inc.
ARA-48	IS	80 acres	Tuolumne River Terrace	Waterford Pit (eastern part) - M.J. Ruddy & Son, Inc.
ARA-49	IS	546 acres	Tuolumne River Channel and Terraces	Waterford Pit - 7/11 Materials, Inc.
ARA-50	IS	1,979 acres	Tuolumne River Channel and Terraces	Roberts Ferry Pit - 7/11 Materials, Inc.; La Grange Pit - M.J. Ruddy & Son, Inc.; Cree Ranch Pit - Western Stone Products, Inc.
ARA-51	S	383 acres	Tuolumne River Terraces	
ARA-52	S	204 acres	Tuolumne River Channel and Terraces	
ARA-53	(S)	29 acres	Tuolumne River Terrace	
ARA-54	IS	24 acres	Tuolumne River Terrace	La Grange Pit - Stanislaus County Dept. of Public Works
ARA-55	IS	38 acres	Tuolumne River Terrace	Sarah Reeves Pit - George Reed, Inc.

S = Immediately Significant: Denotes ARAs that contain lands which are currently permitted for aggregate mining.
S = Highly Significant: Denotes ARAs that contain a minimum of 18 million tons (10 times the threshold value of 1.8 million tons).
S = Significant: Denotes ARAs that contain the minimum threshold value of 1.8 million tons.
S) = Denotes ARAs which must be included with one or more adjacent ARAs to meet the Significant threshold value of 1.8 million tons.

Areas and locations of active pits within the Orestimba Creek Fan and Garzas Creek Fan are identified on Plate 2A. Areas and locations of active pits within Stanislaus River and Tuolumne River channels and terraces are identified on Plate 2C.

including the reserves) within each Aggregate Resource Area. Calculations reflect conditions of the deposits as of January 1, 1993 and do not include resource depletion since that date.

5. Forecast of 50-Year Needs and the Life Expectancy of Current Reserves. The total tonnage of aggregate needed to satisfy the demand in Stanislaus County over the next 50 years is based on multiplying the projected population over that period with the average annual per-capita rate of total aggregate consumption from 1960-1991. Results of this forecast are used to determine the life expectancy of Stanislaus County's current reserves.

6. Identification of Alternative Resources. Alternative sources of aggregate to meet the forecasted 50-year demand are identifie and briefly considered.

OVERVIEW OF THE DESIGNATION PROCESS

This report is the classification phase of the two-step process mandated by SMARA. The classification phase results in a complete product in and of itself. However, at the discretion of the State Mining and Geology Board, a second phase follows receipt and approval of this classification report by the State Mining and Geology Board. Designation is the formal recognition by the State Mining and Geology Board of areas containing minera deposits of regional or statewide significance that should be given special consideration by lead agencies for protection from land uses incompatible with mineral extraction. Recognition is achieved by the adoption of regulations that designate certain deposits to be of prime importance in meeting the future needs o the region or the state. Designation is based upon this report and consultation with lead agencies and other interested parties Procedures for the designation of lands containing significant mineral deposits are specified in Section II.2 of the California State Mining and Geology Board's Guidelines for Classification and Designation of Mineral Lands (1983, p. 23).

Two areas in Stanislaus County have been classified for aggregate resources by the State Geologist in the Division of Mines and Geology Special Report 160 (Jensen and Silva, 1988). One of these areas, a 68-acre area in northwestern Stanislaus County, was designated by the State Mining and Geology Board and is described in the following report: **Designation of Regional Significant Construction Aggregate Resources in the Stockton-Lod Production-Consumption Region (California Department of Conservation, 1990)**. The area designated in that report by the State Mining and Geology Board is shown on Inset Map A of Plate 3.

Regardless of whether the State Mining and Geology Board pursues additional designation of mineral deposits in Stanislaus

County, local governments are still required under SMARA to recognize the information provided in this report, and to emphasize the conservation and development of identified aggregate deposits. To assist local governments in this role, some relative quantification of aggregate resources (both available tonnages and projected demand) provides essential information in the evaluation of proposed land-uses for specific sites. Only with this perspective can sound local decisions regarding the long-term availability of aggregate resources be made.

CONCEPTS USED IN IDENTIFYING AVAILABLE AGGREGATE RESOURCE AREAS

An Aggregate Resource Area (ARA) is an area that has been classified as MRZ-2a or MRZ-2b for concrete-grade aggregate by the State Geologist and is deemed to be available for mining based upon criteria for compatibility provided by the State Mining and Geology Board and summarized in the following paragraph.

For purposes of Aggregate Resource Area identification, incompatible uses of land are defined as improvements of high cost, such as high-density residential developments, developed parklands, intensive industrial developments, commercial developments, and major public facilities. In addition, lands for which the lead agency has approved a tract map or issued an approved Specific Plan are treated as having uses that are incompatible with mining. Lands that have compatible uses are defined as those that are non-urbanized or that have very low density residential development (one unit per ten acres), land that does not have high-cost improvements, and lands used for agriculture, silviculture, grazing or open space.

For this report, determination of the use of lands classified as MRZ-2a or MRZ-2b for concrete-grade aggregate was based upon conditions of the lands at the time of the study (January 1, 1993). The use of the lands was determined after a review of data from lead agencies, reference to aerial photographs and photo-revised topographic maps, and field reconnaissance. The Aggregate Resource Area Map (Plate 3) shows the portions of those areas classified MRZ-2a or MRZ-2b that are considered to have current land uses compatible with mining.

Each Aggregate Resource Area meets or exceeds the State Mining and Geology Board's threshold values for deposits of significant size, and each Aggregate Resource Area may be considered for designation as an area of regional or statewide significance by the State Mining and Geology Board, pursuant to Section 2790 of SMARA. Areas that have not been identified as Aggregate Resource Areas by the State Geologist are not considered for designation by the State Mining and Geology Board.

Although the classification by the State Geologist and the designation by the State Mining and Geology Board are actions explicitly provided for by SMARA, and although the results of such actions yield reports that must be acted upon by affected local governments, the identification of Aggregate Resource Area and the maps in this report delineating those areas do not of themselves carry with them specific obligations imposed on local governments by SMARA. The maps and resource base calculations, however, do contain the essential facts that are needed to focus the attention of planners on the mineral availability problems and the alternative sources of aggregate to meet the mineral resource needs of the region. Without the Aggregate Resource Area maps and the accompanying calculations, the primary objectives of SMARA could not be achieved.

The State Mining and Geology Board's criteria for identifying Aggregate Resource Areas focuses on the apparent suitability of the land for mining and does not take into account conflicting commitments that may restrict the suitability of some areas for mining. It is possible that the available resource base as calculated by the State Geologist may be an over-estimation, and the problems confronting local government may be understated. Considering these possibilities, it becomes important for local governments to carefully review the Aggregate Resource Areas and estimated resources to ensure that planning decisions are made using a correct perspective on available resources.

The State Geologist has divided the Aggregate Resource Area into three categories as follows: **IS (Immediately Significant)**, **HS (Highly Significant)**, and **S (Significant)**. These categories are based on semi-quantitative evaluation of suitable aggregate resources classified as MRZ-2a or MRZ-2b. The criteria for these categories follows:

IS - Aggregate Resource Areas that contain lands that are currently permitted for aggregate mining.

HS - Aggregate Resource Areas that contain in excess of 10 times threshold value of material (approximately 1.8 million tons at 1993 prices in Stanislaus County).

S - All remaining Aggregate Resource Areas containing at least 1.8 million tons of material.

AGGREGATE RESOURCE AREAS IN THE COUNTY

Aggregate Resource Areas are used to focus the attention of land-use planners and local governments on areas that remain accessible for mineral extraction. Mineral land classification, which is done without regard for current land uses, by itself, does very little to put into perspective the resource base that

is available to meet the future needs of a region. The highest probable use of sand and gravel deposits within the identified 55 ARAs in this study is evaluated as concrete-grade aggregate. Sand and gravel thicknesses in ARAs that are currently being mined by aggregate operators and are deemed proprietary are omitted from the following descriptions.

ARAs WITHIN HOSPITAL CREEK FAN (Inset Map A on Plate 3)

ARA-1: That part of the western-most portion of MRZ-$2b^{sg(C1)}$ within the Hospital Creek Fan west of Koster Road and north of Gaffery Road. This 12-acre area is categorized as Significant only if it is included with ARA-2 or ARA-3. Available data indicate that sand and gravel resources within this area are in excess of 75 feet in thickness.

ARA-2: That part of MRZ-$2b^{sg(C1)}$ within the Hospital Creek Fan west of the Delta-Mendota Canal, north of Gaffery Road and east of Koster Road. This 48-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area are in excess of 75 feet in thickness.

ARA-3: That part of MRZ-$2b^{sg(C1)}$ within the Hospital Creek Fan east of the Delta-Mendota Canal, west of Welt Road and north of Gaffery Road. This 561-acre area is categorized as Highly Significant. Available data indicate that sand and gravel resources within this area are in excess of 100 feet in thickness.

Sixty-eight acres in the northwestern portion of this ARA were designated as a regionally Significant construction aggregate resource area by the State Mining and Geology Board as part of the southeastern portion of Sector C-9 in the Stockton-Lodi Production-Consumption Region (California Department of Conservation, 1990; California Administrative Code, Section 3550.8 of Title 14, Division 2, Chapter 8, Subchapter 1)). (The 68-acre designated area of this ARA is shown on inset map A of Plate 3.) Granite Construction Company is currently requesting a mining permit from the Stanislaus County Planning Department to mine about one-half square mile of the western part of this ARA identified as MRZ-$2a^{sg(C1)}$ on Plate 2A (which includes the 68 acres designated by the State Mining and Geology Board).

ARA-4: That part of MRZ-$2b^{sg(C1)}$ east of the Delta-Mendota Canal and south of Gaffery Road. This 6-acre area is the smallest ARA in this report and is categorized as Significant only if it is included with ARA-2 or ARA-3. Available data indicate that sand and gravel resources within this area are in excess of 50 feet in thickness.

ARAs WITHIN ORESTIMBA CREEK FAN (Inset Map B on Plate 3)

ARA-5: Includes the western-most part of MRZ-2b$^{sg(C2)}$ west of the California Aqueduct and west of the power lines. This 192-acre area is categorized as Significant and available data indicate that sand and gravel resources within this area range in thickness from 3 feet to more than 5 feet.

ARA-6: That part of MRZ-2b$^{sg(C2)}$ immediately west of the Californi Aqueduct and east of the power lines. This 107-acre area is categorized as Immediately Significant because Frank B. Marks a Son, Inc. is currently mining concrete-grade aggregate at its Orestimba Creek Pit located in the western half of this ARA (se Plate 2A for location). Available data indicate that sand and gravel reserves and resources within this area range in thickne from 3 feet to more than 6 feet.

ARA-7: That part of MRZ-2b$^{sg(C2)}$ southwest of Orestimba Creek Road and northeast of the California Aqueduct. This 30-acre area is categorized as Significant only if it is included with ARA-13 o ARA-14. Available data indicate that sand and gravel resources within this area range in thickness from 3 feet to more than 6 feet.

ARA-8: That part of MRZ-2b$^{sg(C2)}$ north of Orestimba Creek Road and west of Interstate 5. This 134-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area range in thickness from 3 feet to more than 6 feet.

ARA-9: That part of MRZ-2b$^{sg(C2)}$ east of Interstate 5, north of Stuhr Road, and west of the Delta-Mendota Canal. This 72-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area range in thickness from 6 feet to mo than 9 feet.

ARA-10: That part of MRZ-2b$^{sg(C2)}$ east of Interstate 5, south of Stuhr Road, and west of the Delta-Mendota Canal. This 20-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel thicknesses within this area are probably 6-12 feet thick.

ARA-11: That part of MRZ-2b$^{sg(C2)}$ east of the Delta-Mendota Canal and west of Bell Road. This 7-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area are probably 8-12 feet in thickness.

ARA-12: This ARA includes the entire 180-acre MRZ-2a$^{sg(C2)}$ and tha part of the MRZ-2b$^{sg(C2)}$ located to the east of Bell Road and the Delta-Mendota Canal, north of Stuhr Road, and west of Jorgensen

Road. This 735-acre area is categorized as Immediately Significant because Frank B. Marks and Son, Inc. is currently mining concrete-grade sand and gravel from the 180-acre MRZ-2a$^{sg(C2)}$ area at its Stuhr Road Pit (see Plate 2A for location). A seismic refraction survey was run across this ARA to determine depths of aggregate resources and reserves (see Appendix C). Available data indicate that sand and gravel reserves and resources within this area range in thickness from 15 feet to more than 60 feet.

ARA-13: That part of MRZ-2b$^{sg(C2)}$ east of the Delta-Mendota Canal and south of Stuhr Road. This 177-acre area is categorized as Significant. A seismic refraction survey was run across a portion of this ARA to determine depths of aggregate resources and reserves (see Appendix C). Available data indicate that sand and gravel resources within this area probably range in thickness from 10 feet to more than 30 feet.

ARA-14: That part of MRZ-2b$^{sg(C2)}$ east of Jorgensen Road, south of Anderson Road, west of Eastin Road and north of Stuhr Road. This 223-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area probably range in thickness from 15 feet to more than 25 feet.

ARA-15: That part of MRZ-2b$^{sg(C2)}$ east of Eastin Road, north of Pump Road and south of Anderson Road. This 9-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area probably range in thickness from 10 feet to more than 20 feet. Sand- and finer-sized clasts probably make up 60 percent or more of this deposit at depths to 20 feet.

ARA-16: That part of MRZ-2b$^{sg(C2)}$ east of Eastin Road and north of Pump Road. This 8-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area range in thickness from 10 feet to more than 20 feet. Sand- and finer-sized clasts probably make up 60 percent or more of this deposit at depths to 20 feet.

ARA-17: That part of MRZ-2b$^{sg(C2)}$ east of Eastin Road and south of Pump Road. This 11-acre area is categorized as Significant only if it is included with ARA-13 or ARA-14. Available data indicate that sand and gravel resources within this area range in thickness from 10 feet to more than 20 feet. Sand- and finer-sized clasts probably make up 60 percent or more of this deposit at depths to 20 feet.

ARAs WITHIN GARZAS CREEK FAN (Inset Map C on Plate 3)

ARA-18: That part of MRZ-2b$^{sg(C3)}$ west of the power lines and sout of Sullivan Road. This 21-acre area is categorized as Significa only if it is included with ARA-20. Available data indicate tha sand and gravel resources within this area range in thickness from 3 feet within the active Garzas Creek channel in the western-most part of this area, to more than 8 feet at the eastern end of this area.

ARA-19: That part of MRZ-2b$^{sg(C3)}$ north and west of Sullivan Road. This 35-acre area is categorized as Immediately Significant because it is currently being mined for concrete-grade sand and gravel by the Merced County Department of Roads. Available data indicate that remaining sand and gravel reserves and resources within this area range in thickness from 4 feet to more than 12 feet.

ARA-20: That part of MRZ-2b$^{sg(C3)}$ south and east of Sullivan Road, and west of the California Aqueduct. This 110-acre area is categorized as Significant. Available data indicate that sand a gravel resources within this area are probably 5-15 feet thick. Aggregate resources are likely to be thicker in the eastern portion of this ARA.

ARA-21: That part of MRZ-2b$^{sg(C3)}$ south of Sullivan Road, east of the California Aqueduct and west of Interstate 5. This 39-acre area is categorized as Significant only if it is included with ARA-20. Available data indicate that sand and gravel resources within this area probably range in thickness from 4 feet observe within the Garzas Creek channel to more than 15 feet.

ARA IN THE CALAVERAS RIVER TERRACE (Inset Map D on Plate 3)

ARA-22: This ARA includes the 570-acre MRZ-2a$^{sg(C3)}$ area and the 262-acre MRZ-2b$^{sg(C4)}$ area shown on Plate 2C. It is located east o Waverly Road and south of the Calaveras River in northeastern Stanislaus County. The northern three-fourths of this area was classified as MRZ-3 in the Division of Mines and Geology's Special Report 160 (Jensen and Silva, 1988, Plate 8). Granite Construction Company is currently requesting a permit to mine th MRZ-2a$^{sg(C3)}$ area for concrete-grade aggregate. (This proposed quarry location is shown as the Mueller Ranch Site on Plate 2C.) This 832-acre ARA is categorized as Highly Significant. The northern third of this area was dredged for gold during the 1930s. Available data indicate that sand and gravel resources within this ARA range in thickness from 60 feet to more than 75 feet.

ARAs IN THE STANISLAUS RIVER CHANNEL AND TERRACES (Inset Map E on Plate 3)

ARA-23: That part of MRZ-2b$^{sg(C5)}$ east of McHenry Road, south of River Road, west of Santa Fe Road and north of Patterson Road. This 880-acre ARA is categorized as Immediately Significant because George Reed, Inc., is currently mining concrete-grade sand and gravel at its Munn & Perkins Pit in the northwestern portion (see Plate 2A for mine location and boundary). Concrete-grade aggregate has been mined at sites within this ARA from the active Stanislaus River channel and from adjacent elevated and nested terraces since the early 1900s. Available data indicate that remaining sand and gravel reserves and resources within this area range in thickness between 7-25 feet.

ARA-24: That part of MRZ-2b$^{sg(C5)}$ east and north of Burlwood Road. This 7-acre area is categorized as Significant only if it is included with ARA-23. Available data indicate that sand and gravel resources within this area are probably 8-12 feet thick.

ARA-25: That part of MRZ-2b$^{sg(C5)}$ east of Henry Road and north of Lee Avenue. This 16-acre area is categorized as Significant only if it is included with ARA-23 or ARA-26. Available data indicate that sand and gravel resources within this area could be from 5-12 feet thick.

ARA-26: This ARA includes the 192-acre MRZ-2a$^{sg(C4)}$ area and that part of MRZ-2b$^{sg(C5)}$ east of Santa Fe Road, north of Riverbank, west of Liberini Avenue, and south of River Road. This 2,492-acre area is categorized as Immediately Significant because George Reed, Inc. is currently mining concrete-grade sand and gravel from its Riverbank Pit in the southern half of MRZ-2a$^{sg(C4)}$ (see Plate 2C for mine location and boundary). Much of this extensive area is covered by a thick soil overburden (5-30 feet thick). Most of this area is used for agricultural purposes and has yet to be explored by drill holes for the presence of sand and gravel. Although extensive subsurface data is not available for this area, available data indicates that sand and gravel resources within this ARA most likely range in thickness between 10-25 feet.

ARA-27: That part of MRZ-2b$^{sg(C5)}$ east of Liberini Avenue, south of River Road, and west of Valley Home Road. This 108-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area range in thickness between 6-25 feet.

ARA-28: That part of MRZ-2b$^{sg(C5)}$ east of the Southern Pacific Railroad, south of Gilbert and Rodden Roads, and west of Kerr Park. This 186-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area range in thickness between 6-10 feet.

ARA-29: That part of MRZ-2b$^{sg(C5)}$ south of Rodden Road and northwest of Atlas Road. This 66-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area range in thickness between 15-20 feet

ARA-30: That part of MRZ-2b$^{sg(C5)}$ east of Atlas Road, south of Rodden Road and east of Gray Road. This 309-acre area is categorized as Significant. Available data indicate that sand an gravel resources within this area most likely range in thickness between 8-15 feet.

ARA-31: That part of MRZ-2b$^{sg(C5)}$ east and south of Orange Blossom Road, and north of Lancaster Road. This 113-acre area is categorized as Significant only if it is included with ARA-30. Available data indicate that sand and gravel resources within this area probably range in thickness between 8-15 feet.

ARA-32: That part of MRZ-2b$^{sg(C5)}$ south of Lancaster Road and nort of State Route 120. This 28-acre area is categorized as Significant only if it is included with ARA-30. Available data indicate that sand and gravel resources within this area probabl range in thickness between 6-12 feet.

ARA-33: That part of MRZ-2b$^{sg(C5)}$ north of Orange Blossom Road, east of Olive Road and west of Stone Avenue. This 28-acre area i categorized as Significant only if it is included with ARA-30. Available data indicate that sand and gravel resources within this area range in thickness between 6-20 feet.

ARA-34: That part of MRZ-2b$^{sg(C5)}$ south of State Route 120. This 79-acre area is categorized as Significant only if it is include with ARA-30. Available data indicate that sand and gravel resources within this area most likely range in thickness betwee 6-12 feet.

ARA-35: That part of MRZ-2b$^{sg(C5)}$ northeast of Stone Road and northwest of Orange Blossom Road. This 52-acre area is categorized as Significant only if it is included with ARA-30. Available data indicate that sand and gravel resources within this area most likely range in thickness between 8-20 feet.

ARA-36: That part of MRZ-2b$^{sg(C5)}$ southeast of Orange Blossom Road and northwest of State Route 120. This 30-acre area is categorized as Immediately Significant because George Reed, Inc. is currently mining concrete-grade aggregate at its Ardis Pit, which forms the boundary of this ARA (see Plate 2C for mine location and boundary).

ARA-37: That part of MRZ-2b$^{sg(C5)}$ southeast of State Route 120. This 88-acre area is categorized as Immediately Significant because George Reed, Inc. is currently mining concrete-grade aggregate from its 16-acre Hodge Ranch Pit in the northwestern

portion of this ARA (see Plate 2C for mine location and boundary). Available data indicate that sand and gravel reserves and resources within this area range in thickness between 10-25 feet.

ARA-38: That part of MRZ-2b$^{sg(C5)}$ south of Morrison and Frymire Roads, north of State Route 120, and west of Sonora Road. This 544-acre area is categorized as Highly Significant. Past aggregate mining within this ARA indicate the remaining sand and gravel resources are hard, durable and extensive. Available data indicate that sand and gravel resources within this area range in thickness between 20-35 feet.

ARA-39: That part of MRZ-2b$^{sg(C5)}$ southwest of State Route 120. This 47-acre area is categorized as Immediately Significant because Karl Ohe is currently mining concrete-grade sand and gravel from his 8-acre Willms Ranch Pit in the central portion of this ARA (see Plate 2C for mine location and boundary). Available data indicate that remaining sand and gravel reserves and resources within this area range in thickness between 5-35 feet.

ARA-40: That part of MRZ-2b$^{sg(C5)}$ southeast of State Route 120. This 25-acre area is categorized as Significant only if it is included with ARA-38. Available data indicate that sand and gravel resources within this area range in thickness between 8-20 feet.

ARA-41: That part of MRZ-2b$^{sg(C5)}$ northwest of Kennedy Road and east of Sonora Road. This 87-acre area is categorized as Significant. Portions of this area have been disturbed by previous gold mining activities. Available data indicate that sand and gravel resources within this area range in thickness between 6-15 feet.

ARAs IN THE TUOLUMNE RIVER CHANNEL AND TERRACES (Inset Map F on Plate 3)

ARA-42: That part of MRZ-2b$^{sg(C6)}$ west of Albers Road and north of the Tuolumne River. This 18-acre area is categorized as Significant only if it is included with ARA-44. Available data indicate that sand and gravel resources within this area range in thickness between 25-30 feet.

ARA-43: That part of MRZ-2b$^{sg(C6)}$ west of Geer Road and south of the Tuolumne River. This 22-acre area is categorized as Immediately Significant because it is currently being mined by Western Stone Products, Inc. for concrete-grade sand and gravel and forms the eastern portion of its Schmidt Pit (see Plate 2C for mine location and boundary).

ARA-44: That part of MRZ-2b$^{sg(C6)}$ south of Jantzen Road, east of Albers Road and north of the Tuolumne River. This 57-acre area is categorized as Significant. Available data indicate that sand and gravel resources within this area range in thickness between 20-30 feet.

ARA-45: That part of MRZ-2b$^{sg(C6)}$ north of John Fox Road and southeast of Fox Grove Park. This 12-acre area is categorized as Immediately Significant because it is currently being mined by Western Stone Products, Inc. for concrete-grade sand and gravel. The boundaries of this ARA form Western Stone Product, Inc.'s Landmark Pit (see Plate 2C for mine locations and boundaries).

ARA-46: Includes the 563-acre MRZ-2a$^{sg(C5)}$ and that part of MRZ-2b$^{sg(C6)}$ north of John Fox and Delaware Roads, west of Hickman Road, and south of Riverside Road. This 995-acre area is categorized as Immediately Significant because Western Stone Products, Inc. is currently mining the western-most portion (Warner Pit) and the eastern portion (Hickman Pit) for concrete-grade sand and gravel (see Plate 2C for mine locations and boundaries).

ARA-47: Includes the western half of MRZ-2a$^{sg(C6)}$ and that part of MRZ-2b$^{sg(C6)}$ east of Hickman Road, south of State Route 132 and north of Lampley Road. This 1,165-acre area is categorized as Immediately Significant for the following two reasons: (1) George Reed, Inc. has mined concrete-grade aggregate from a 23-acre portion of this area in the past and is currently permitted to mine concrete-grade sand and gravel from its 312-acre Waterford Site located in the center of this ARA; and (2) M.J. Ruddy, Inc. is currently mining concrete-grade aggregate at its Waterford Pit located in the eastern part of this ARA (see Plate 2C for locations and mine boundaries). Available data indicate that the remaining sand and gravel reserves and resources within this area range in thickness between 15-30 feet.

ARA-48: That part of MRZ-2a$^{sg(C6)}$ north of the Turlock Main Canal and south of the Tuolumne River. This 80-acre area is categorized as Immediately Significant because it is currently being mined for concrete-grade sand and gravel by Western Stone Products, Inc., and is within the eastern portion of its Waterford Pit. Available data indicate that the remaining sand and gravel reserves and resources within this area range in thickness between 15-30 feet.

ARA-49: Includes the eastern third of MRZ-2a$^{sg(C6)}$ and that part of MRZ-2b$^{sg(C6)}$ south of State Route 132, north of the Turlock Main Canal and west of Roberts Ferry Road. This 546-acre area is categorized as Immediately Significant because concrete-grade aggregate is currently being mined at 7/11 Materials, Inc.'s, Waterford Pit which makes up the western half of this ARA. Available data indicate that the remaining sand and gravel

reserves and resources within this area range in thickness between 5-30 feet.

ARA-50: Includes all of the 672-acre MRZ-2a$^{sg(C7)}$ and that part of MRZ-2b$^{sg(C6)}$ south of State Route 132, east of Roberts Ferry Road, north of Lake Road and west of Basso Bridge. This 1,979-acre area is categorized as Immediately Significant because three aggregate producers are currently mining concrete-grade aggregate from three sites in this ARA: (1) 7/11 Materials, Inc.'s Roberts Ferry Pit; (2) M.J. Ruddy & Son, Inc.'s La Grange Pit; and (3) Western Stone Product, Inc.'s Cree Ranch Pit (see Plate 2C for locations and mine boundaries). The eastern four-fifths of this area have been dredged for gold. The uppermost 10-20 feet in the eastern third of this area was scalped for aggregate during the late 1960s and early 1970s and used in the Don Pedro Dam. Available data indicate that remaining sand and gravel reserves and resources within this area range in thickness between 10-35 feet.

ARA-51: That part of MRZ-2b$^{sg(C6)}$ south of Lake Road, west of La Grange Road and Dawson Lake, and north of the Turlock Main Canal. This 383-acre area is categorized as Significant. All of this area has been dredged for gold. The uppermost 15-20 feet over nearly 80 percent of this area was scalped for aggregate during the late 1960s and early 1970s and used in the Don Pedro Dam. Available data indicate that remaining sand and gravel resources within this area range in thickness between 10-15 feet.

ARA-52: That part of MRZ-2b$^{sg(C6)}$ north and west of State Route 132 and northeast of Basso Bridge. This 223-acre area is categorized as Significant. All of this area has been dredged for gold. The uppermost 15-20 feet of this area was scalped for aggregate during the late 1960s and used in the Don Pedro Dam. Available data indicate that remaining sand and gravel resources within this area range in thickness between 5-15 feet.

ARA-53: That part of MRZ-2b$^{sg(C6)}$ south of State Route 132, west of La Grange Road, and north of Dawson Lake. This 29-acre area is categorized as Significant only if it is included with ARA-52. Available data indicate that sand and gravel resources within this area range in thickness between 10-15 feet.

ARA-54: That part of MRZ-2b$^{sg(C6)}$ east of La Grange Road, west of Old La Grange Road, and north of Tuolumne River. This 24-acre area is categorized as Immediately Significant because Stanislaus County Department of Public Works is currently extracting modest amounts of concrete-grade sand and gravel from this ARA. This area has been dredged for gold. Available data indicate that remaining sand and gravel reserves within this area range in thickness from 8-12 feet.

ARA-55: That part of MRZ-2b$^{sg(C6)}$ east of Old La Grange Road, south of the Modesto Main Canal and north of the Tuolumne River. This 38-acre area is categorized as Immediately Significant because George Reed, Inc. is currently mining concrete-grade sand and gravel at its Sarah Reeves Pit in the northern third of this ARA. Much of this area was previously dredged for gold.

PART VI

EVALUATION OF PRESENT AND FUTURE USE OF CONSTRUCTION AGGREGATE IN STANISLAUS COUNTY

PART VI - EVALUATION OF PRESENT AND FUTURE USE OF CONSTRUCTION AGGREGATE IN STANISLAUS COUNTY

This section of the report contains an assessment of the total reserves of aggregate in Stanislaus County and addresses some of the considerations that will effect the life span of those reserves.

AGGREGATE PRODUCTION IN STANISLAUS COUNTY

In 1991, 2,583,000 tons of concrete-grade aggregate worth over $11,130,000 were mined in Stanislaus County. Nearly 95 percent of this amount was consumed within Stanislaus County. Approximately 80 percent of the aggregate produced was used as PCC aggregate or in related products such as gunite, plaster sand, mortar sand, and stucco. This high-quality material makes up the bulk of such construction projects as abutments, buildings, building foundations, bridges, airports, and construction projects in general. Approximately 20 percent of the aggregate produced during 1991 was used as AC and road base aggregate.

At the time of this study the following operators were either actively mining aggregate or had permits to mine aggregate in Stanislaus County:

Frank B. Marks & Son, Inc.; Stuhr Road Pit and Orestimba Creek Pit
George Reed, Inc.; Ardis Pit, Sarah Reeves Pit, Hodge Ranch Pit, and Waterford Site
Lee White; Zacharias Road Pits
Merced County Department of Roads; Garzas Creek Pit
M.J. Ruddy & Son, Inc.; Waterford Pit and La Grange Pit
Ohe Sand and Gravel; Willms Pit
7/11 Materials, Inc.; Waterford Pit and Roberts Ferry Pit
Stanislaus County Department of Public Works; La Grange Pit
Western Stone Products, Inc.; Schmidt Pit, Landmark Pit, Charles D. Warner & Son, Inc. Pit, and Cree Ranch Pit
Langford/Ripley; Shirley Creek and Hoods Creek Site

There are no crushed stone quarry operations within Stanislaus County. About 95 percent of the aggregate mined in Stanislaus is consumed within the county and an additional 25 percent of the aggregate consumed within Stanislaus County is imported from producing areas outside of the county. These producing areas outside of the county include the Corral Hollow Fan and the Hospital Creek Fan in southwestern San Joaquin County, Stanislaus River terrace deposits in the Riverbank area in southern San Joaquin County, and the Table Mountain Quarry in southwestern Tuolumne County.

Figure 9 shows the production of construction aggregate in Stanislaus County for the years 1960 to 1991. The historical aggregate production data for Stanislaus County for the years 1960-1990 were obtained from mining records of the U.S. Department of the Interior, Bureau of Mines. Production data for 1991 were obtained from proprietary records supplied by the aggregate operators included in this study area. The U.S. Bureau of Mines records are compiled from responses to voluntary questionnaires that are sent regularly to all known mining operators. Each producer is requested to divulge the production from each of its producing properties every other year. The degree of accuracy of these statistics depends on the completeness of the U.S. Bureau of Mines canvass and on the producer's response.

Aggregate production has increased from 770,000 tons in 1960 to 2,583,000 in 1991, an increase of more than 335 percent (Table 7). The enormous increase in production is largely due to the local demand of aggregate and by an increased population growth rate. In the past 20 years, many communities in Stanislaus County have gained an influx of people from the more urbanized San Francisco Bay region. An increased population requires an increased number of schools, houses, offices, and roads. In addition, some of the increased aggregate production since 1960 has been the result of large public works projects such as the California Aqueduct, the Don Pedro Dam, and the construction and maintenance of Interstate 5.

AGGREGATE RESERVES IN STANISLAUS COUNTY

Construction aggregate reserve and resource figures in this report were based on the combined concrete-grade aggregate reserve tonnages of the above operators. Concrete-grade sand and gravel reserves within Stanislaus County are 27,700,000 tons. This reserve base represents a starting point for planning purposes as of 1993. This is not a static number because these reserves will progressively be depleted as production continues.

Aggregate Resource Areas (see the previous section) identified as Immediately Significant (IS) are important to the county because they contain resources that are presently permitted for mining and represent the current resources of construction aggregate in Stanislaus County as well as the most likely sources of construction aggregate in the near future. A more specific term for these permitted resources is **reserves**. In this study **reserves** are aggregate resources that have been determined to be acceptable for commercial use, that exist within properties owned or leased by aggregate producing companies, and for which permits have been granted to allow mining and

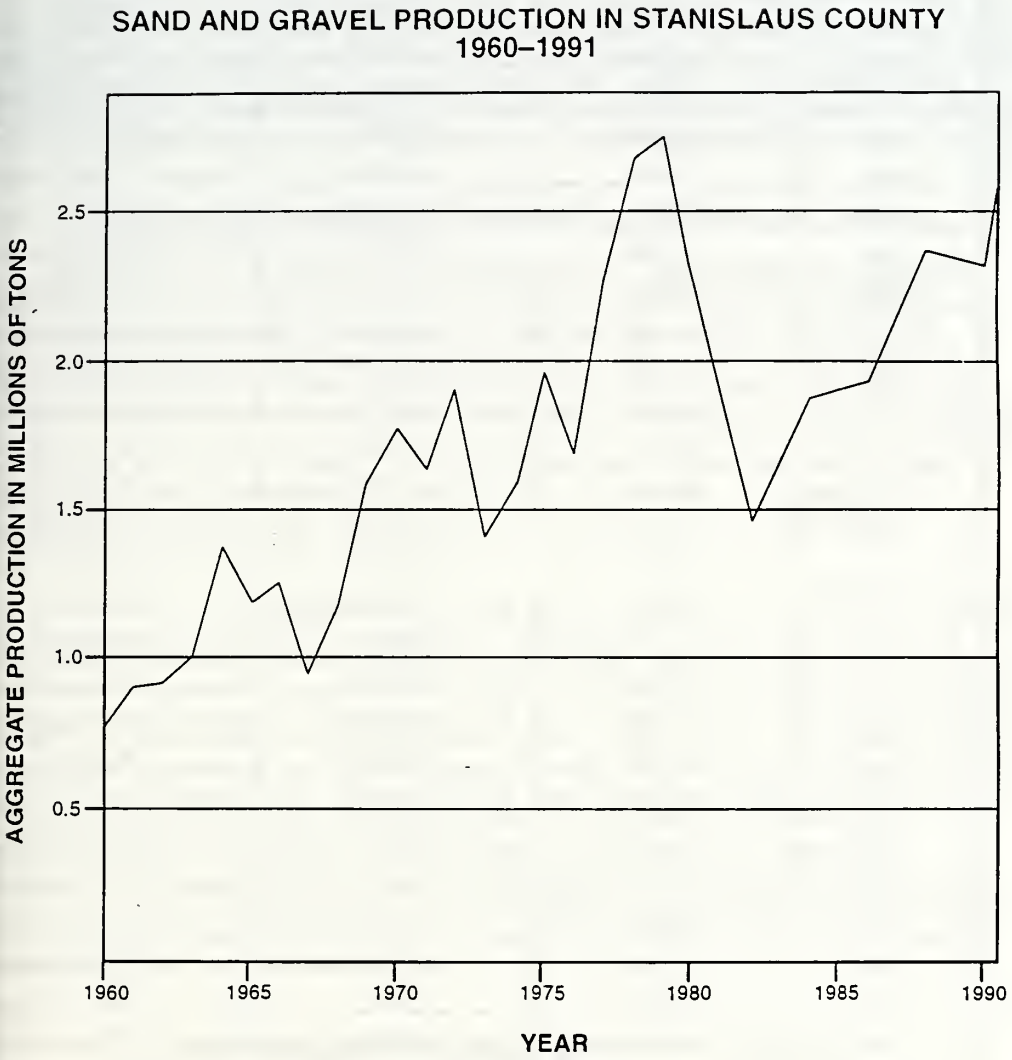


FIGURE 9. – Aggregate production in Stanislaus County for the years 1960 to 1991. Data compiled from the U.S. Bureau of Mines records and individual companies.

Table 7. Population, aggregate production and consumption (tons), and per-capita consumption (tons) in Stanislaus County during the years 1960-1991.

YEAR	POPULATION*	AGGREGATE PRODUCTION AND CONSUMPTION (tons)**	AVERAGE ANNUAL PER-CAPITA CONSUMPTION (tons)
1960	157,294	770,000	4.9
1961	161,145	903,000	5.6
1962	164,995	934,100	5.7
1963	168,846	1,005,000	6.0
1964	172,269	1,366,000	7.9
1965	176,547	1,195,000	6.8
1966	180,398	1,250,000	6.9
1967	184,248	938,000	5.1
1968	188,099	1,177,000	5.9
1969	191,949	1,633,000	8.5
1970	195,800	1,784,000	9.1
1971	203,000	1,644,000	8.1
1972	210,200	1,912,000	9.1
1973	217,400	1,403,000	6.5
1974	224,600	1,574,000	7.0
1975	231,800	1,965,000	8.5
1976	238,900	1,688,000	7.1
1977	246,100	2,266,000	9.2
1978	253,300	2,686,000	10.6
1979	260.100	2,756,000	10.6
1980	267,000	2,283,000	8.5
1981	274,600	XXX	XXX
1982	281,400	1,460,000	5.2
1983	288,300	XXX	XXX
1984	295,100	1,879,380	6.4
1985	302,600	XXX	XXX
1986	312,600	1,945,000	6.2
1987	325,200	XXX	XXX
1988	338,300	2,385,000	7.1
1989	354,200	XXX	XXX
1990	376,100	2,329,000	6.2
1991	382,300	2,583,000	6.8

Average annual per-capita consumption for 1960-1991 is 7.3 tons.
*Population statistics taken from California Statistical Abstracts, October 1992 and were derived from the California Department of Finance, Demographic Research Unit.
**U.S. Bureau of Mines production statistics combined for all mines in Stanislaus County for the years 1960-1990. Annual production statistics are reported every other year starting in 1980.

processing. **Resources** include **reserves** as well as all potentially useable aggregate materials that may be mined in the future, but for which no permit allowing mining has been granted, or for which marketability has not been established.

There is no significant sand and gravel recharge in the Stanislaus or Tuolumne Rivers because they are dammed a few miles upstream from the Stanislaus-Tuolumne County line. Although there is some annual sand and gravel recharge within Orestimba and Garzas Creeks, the tonnages are negligible when compared with the annual production and consumption of aggregate within the county.

DEPLETION OF AGGREGATE RESERVES IN STANISLAUS COUNTY

Because the demand for construction aggregate is largely dependent on the population of an area (Anderson and others, 1979), the projected increase in aggregate requirements for Stanislaus County can be forecasted by examining projected population growth. The California State Department of Finance (1993) is projecting profound population growth within Stanislaus County. From 1960 to 1992 the population of Stanislaus County has increased by 150 percent. By the year 2040 Stanislaus County population is projected to swell to 1,224,000, an additional increase of more than 211 percent (Figure 10; California Department of Finance, 1993).

Because increased population will create an increased demand for aggregate products, expanded aggregate production within Stanislaus County will depend on (1) the ability of the aggregate producers to increase plant output, and (2) for lead agencies to expand the aggregate reserve base by permitting additional mining sites. At the rate of production from 1960-1991, the identified aggregate reserves in Stanislaus County will be depleted by the year 2002 (Figure 11). Permitting new aggregate mine sites will significantly increase the reserve base of concrete-grade aggregate within Stanislaus County. However, the expected longevity of aggregate reserves is based on the assumption that mining will continue until the reserves are depleted. Encroaching urbanization, especially in and near scenic riparian areas, could threaten these reserves.

AGGREGATE RESOURCES IN STANISLAUS COUNTY

As stated previously, **resources** include **reserves** as well as all potentially usable aggregate materials that may be mined in the future, but for which no permit allowing mining has been granted, or for which marketability has not been established.

Concrete-grade aggregate resources are located in six geographic areas of Stanislaus County. Total estimated

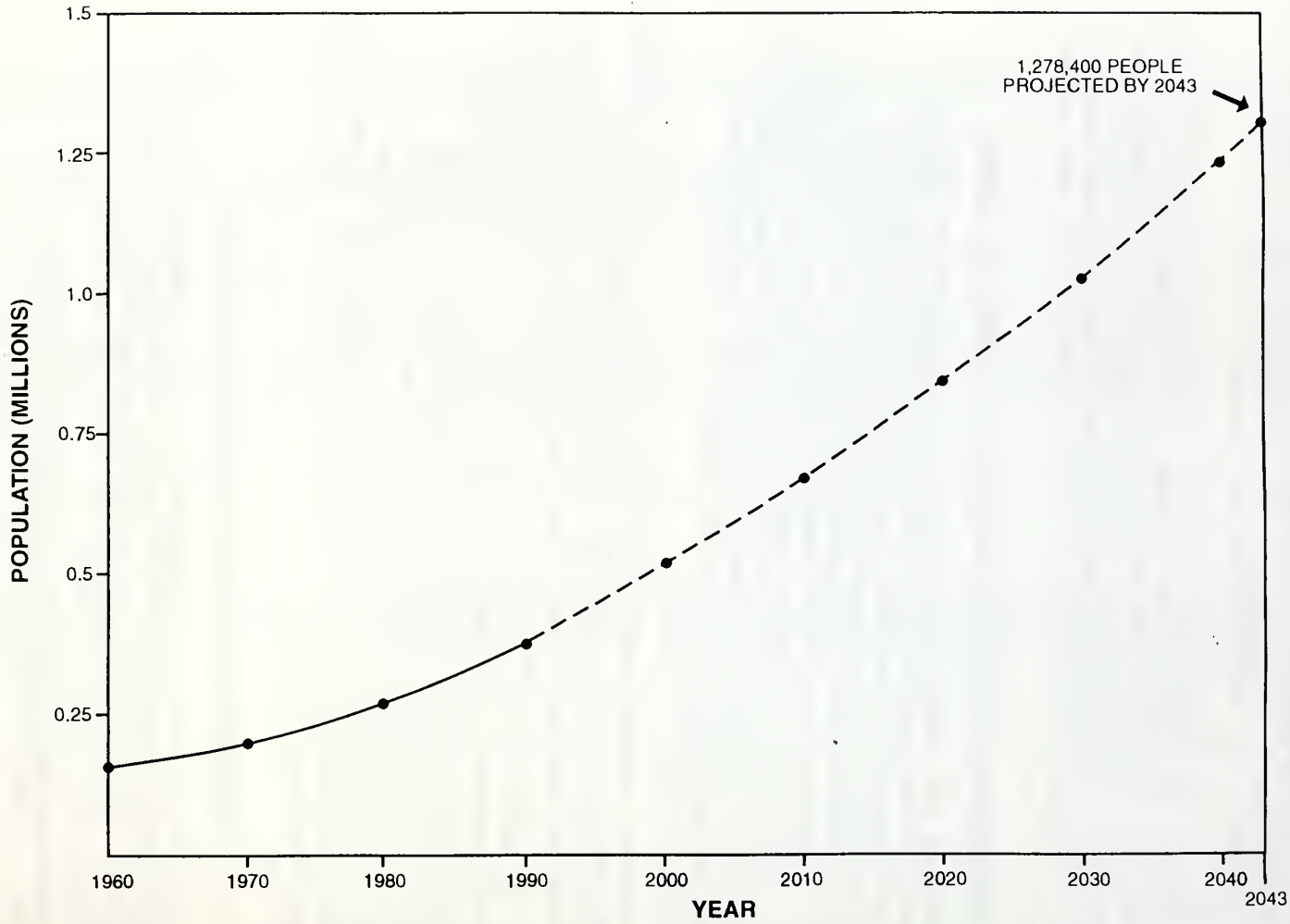


FIGURE 10. – Stanislaus County population from 1960 - 1990.* Projected County population to the year 2043.**

*Data from California Statistical Abstracts, October 1992 (derived from California Department of Finance, Demographic Research Unit).

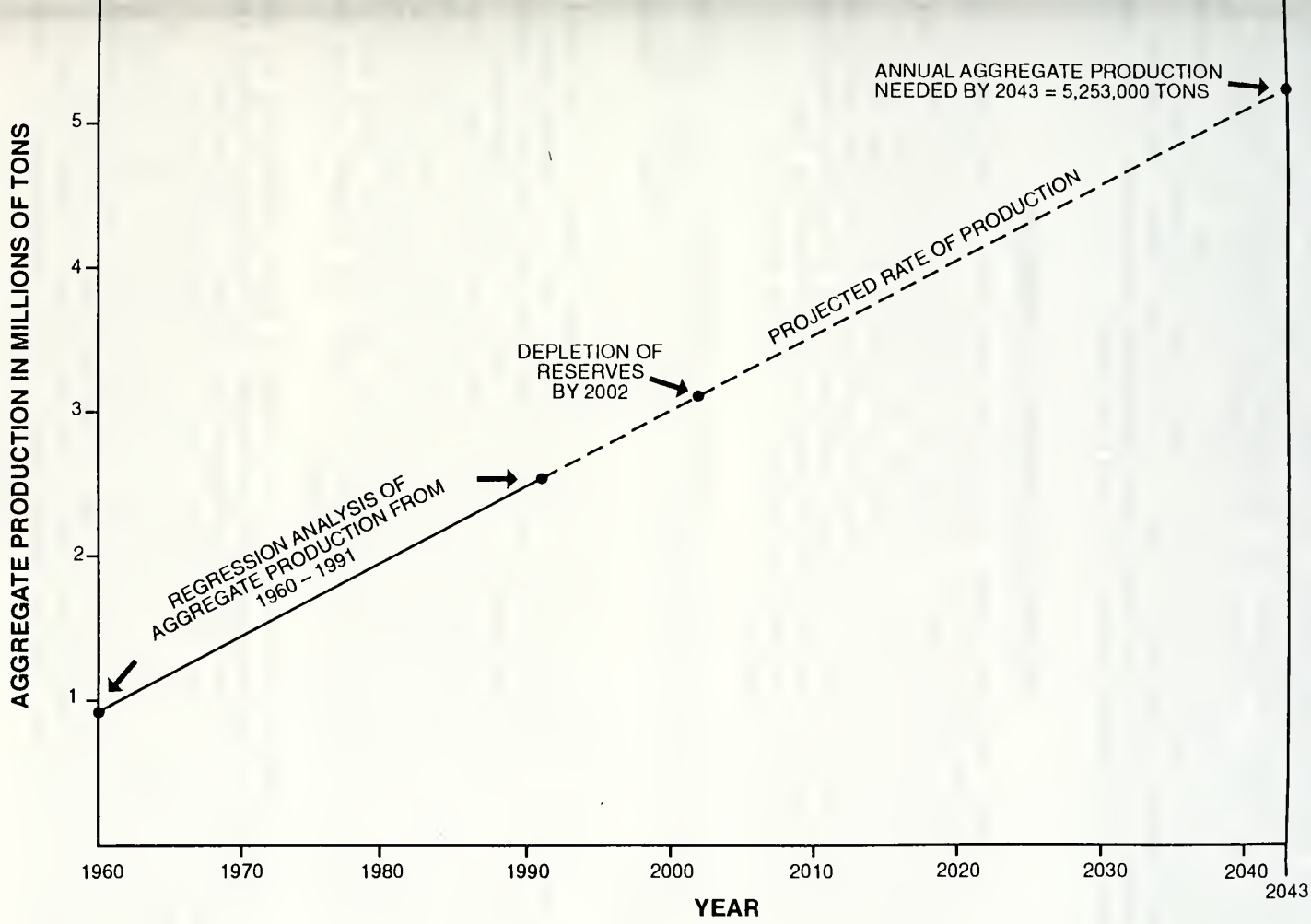


FIGURE 11. – Projected depletion dates of aggregate reserves in Stanislaus County based on the increase in population from the years 1960 to 1991.

concrete-grade resources for each of the six areas are: Hospital Creek Fan in northwestern Stanislaus County (83 million tons), Orestimba Creek Fan in western Stanislaus County (51 million tons), Garzas Creek Fan in southwestern Stanislaus County (5 million tons), Calaveras River elevated terrace in northeastern Stanislaus County (55 million tons), Stanislaus River in eastern Stanislaus County (129 million tons), and Tuolumne River in southeastern Stanislaus County (217 million tons). Estimated tonnages for all concrete-grade aggregate resources in the study area total approximately 540 million tons.

ALTERNATIVE SOURCES OF AGGREGATE

Other than the areas classified MRZ-2a$^{sg(C)}$ or MRZ-2b$^{sg(C)}$ for construction aggregate in Stanislaus County, many areas are classified as MRZ-3a$^{sg(C)}$. The areas classified as MRZ-3a$^{sg(C)}$ may prove suitable for future sources of construction aggregate (Table 5). Exploration of these areas could determine their aggregate potential. For example, geologic investigations such as seismic surveys and drilling, combined with aggregate sampling and engineering testing procedures, could determine the suitability of the sand and gravel in these areas for construction aggregate.

In addition to areas classified as MRZ-3a$^{sg(C)}$, many indurated metamorphic and igneous units that occur in the western and eastern portions of the County are potential sources of crushed stone.

Major sources of construction aggregate occur in production areas a few miles adjacent to Stanislaus County. George Reed, Inc.'s Munn & Perkins Pit south of Escalon and its Table Mountain Quarry, a few miles east of Knights Ferry, supply important amounts of AC into northern and northeastern Stanislaus County. Valley Rock's South Bird Road Pit, Brown Sand, Inc.'s Vernalis Pit, and the newly permitted Teichert Aggregates' Vernalis Quarry provide or will provide aggregate to the northwestern and north-central portions of Stanislaus County. In addition, many millions of tons of concrete-grade dredge tailings are present along the Merced River, south of La Grange.

The massive tonnages of San Joaquin River sands may be used to extend concrete-aggregate resources in Stanislaus County (see MRZ-3a$^{sg(C16)}$ on Plate 2B). Aggregate producers, such as FTG Materials, Inc. and Brown Sand, Inc. are currently mining unconsolidated fine-grained San Joaquin River channel sand in San Joaquin County south of Manteca. They report that the coarse 15 percent to 20 percent fraction of these sands can be processed and blended with coarser-sized sands for use in shotcrete, stucco, mortar sand, roofing tiles, and plaster sand. These medium- and fine-grained sands have a high percentage of quartz

grains and are proven to be concrete-grade. To augment and extend decreasing concrete-grade aggregate resources identified within the MRZ-2 zones, it may be economically feasible to mine and process the coarser-sized fraction of these San Joaquin River channel sands in Stanislaus County.

PART VII

CONCLUSIONS

PART VII - CONCLUSIONS

Mining in Stanislaus County has produced commodities from each of the three main groups of mineral resources, which include construction aggregate, industrial minerals, and metallic minerals. Among these commodities, sand and gravel is presently the only one mined. For the near future, sand and gravel will continue to be the most important mineral resource produced in the county. Among other commodities mined previously, those with the highest potential include kaolinitic clay and diatomite. Among commodities never mined, construction aggregate (in the form of crushed stone), and specialty sand have the most potential for development.

At present and for the near future, the most important area of Stanislaus County for mineral resources is the upstream portion of the Tuolumne River from Waterford to La Grange--an area with eleven producing aggregate mines and substantial concrete-grade aggregate resources. Other important mineral resource deposits can be found in the upper Stanislaus River, the Sierra Nevada foothills between Knights Ferry and La Grange, the foothills area of the Coast Ranges west of Newman, a small area in the very northern tip of the county, and several alluvial fans adjacent to the Coast Ranges in the vicinity of Interstate 5.

A total of about 32 square miles of land in the county have been classified as either MRZ-2a or MRZ-2b, which are zones that indicate significant mineral resources are known or inferred to be present. A list of each of the areas classified is presented in Table 8. Of the 32 square miles of land classified as either MRZ-2a or MRZ-2b, 92 percent of this area is classified for construction aggregate in the form of sand and gravel. The remaining percentage is apportioned among nine separate areas classified for industrial minerals, including kaolinitic clay, diatomite, quartz (silica), and specialty sand.

CONSTRUCTION AGGREGATE RESOURCES

Thirteen separate areas in the study area are classified as MRZ-2a$^{sg(C)}$ or MRZ-2b$^{sg(C)}$ (areas of identified mineral resource significance) for construction aggregate within six geographic areas (Plates 2A and 2C). These six geographic areas are: (1) Hospital Creek Fan, (2) Orestimba Creek Fan, (3) Garzas Creek Fan, (4) Calaveras River elevated terrace, (5) the Stanislaus River, and (6) the Tuolumne River. A total of 5.82 square miles are classified as MRZ-2a$^{sg(C)}$, and 23.57 square miles are classified as MRZ-2b$^{sg(C)}$ for concrete-grade aggregate in the six areas. The combined area of these 13 MRZ-2 areas is 29.39 square miles, which represents about 2 percent of the total land area of Stanislaus County. The measured land area encompassed by each MRZ-2 boundary and its geographic area are presented on Table 8.

Table 8. Areas classified MRZ-2.

GEOGRAPHIC AREAS CLASSIFIED AS MRZ-2	MRZ IDENTIFICATION	COMMODITY	SQ. MI.
Hospital Creek Fan, Vernalis Site	$2a^{1g(C1)}$	Concrete aggregate	0.50
Orestimba Creek Fan, Stuhr Road Quarry	$2a^{1g(C2)}$	Concrete aggregate	0.28
Calaveras River, Elevated Terrace Site	$2a^{1g(C3)}$	Concrete aggregate	0.89
Stanislaus River, Riverbank Area	$2a^{1g(C4)}$	Concrete aggregate	0.30
Tuolumne River, Hatch Road Area	$2a^{1g(C5)}$	Concrete aggregate	0.88
Tuolumne River, Waterford Area	$2a^{1g(C6)}$	Concrete aggregate	1.92
Tuolumne River, Roberts Ferry Area	$2a^{1g(C7)}$	Concrete aggregate	1.05
Hospital Creek Fan	$2b^{1g(C1)}$	Concrete aggregate	1.05
Orestimba Creek Fan	$2b^{1g(C2)}$	Concrete aggregate	2.70
Garzas Creek Fan	$2b^{1g(C3)}$	Concrete aggregate	0.32
Calaveras River Elevated Terrace	$2b^{1g(C4)}$	Concrete aggregate	0.41
Stanislaus River	$2b^{1g(C5)}$	Concrete aggregate	12.49
Tuolumne River	$2b^{1g(C6)}$	Concrete aggregate	6.60
Kraftile Pit	$2a^{1(K1)}$	Kaolinitic clay	0.08
49er Pit	$2b^{1(K1)}$	Kaolinitic clay	0.14
Curtoni Pit	$2b^{1(K2)}$	Kaolinitic clay	0.22
Northwest of La Grange	$2b^{1(K3)}$	Kaolinitic clay	0.11
Crow Hill	$2b^{1(D1)}$	Diatomite	1.75
Hammond Mine	$2b^{1(Q1)}$	Quartz silica	0.01
South of Orestimba Creek	$2b^{1(S1)}$	Specialty sand	0.16
South of Cooperstown	$2b^{1(S2)}$	Specialty sand	0.06
Northwest of La Grange	$2b^{1(S3)}$	Specialty sand	0.11
		TOTAL MRZ-2 AREA:	32.03 mi^2

*The total area classified as MRZ-2 represents about 2.11% of the total land area in Stanislaus County.

Of the 13 areas classified as MRZ-$2a^{sg(C)}$ or MRZ-$2b^{sg(C)}$, approximately 22 square miles are identified as 55 separate Aggregate Resource Areas. An Aggregate Resource Area (ARA) is an area that has been classified MRZ-$2a^{sg(C)}$ or MRZ-$2b^{sg(C)}$ by the State Geologist and is deemed to be available for mining based on criteria for compatibility provided by the State Mining and Geology Board (Table 6).

Seventeen Aggregate Resource Areas contain active mines. There are 20 active mines within these 17 ARAs: 18 mines are currently operated by six different commercial companies, and two mines are operated by two different governmental agencies. All of these active mines are producing portland cement concrete-grade aggregate. These 17 ARAs containing active mines total approximately 14.48 square miles which represents about 0.95 percent of the total area of Stanislaus County. All of the 17 ARAs containing active mines are identified as **Immediately Significant** and are summarized below.

ARA-6 Orestimba Pit - Frank B. Marks & Son, Inc.
ARA-12 Stuhr Road Pit - Frank B. Marks & Son, Inc.
ARA-19 Garzas Creek Pit - County of Merced Depart. of Roads
ARA-23 Munn & Perkins Pit - George Reed, Inc.
ARA-26 Riverbank Pit - George Reed, Inc.
ARA-36 Ardis Pit - George Reed, Inc.
ARA-37 Hodge Ranch Pit - George Reed, Inc.
ARA-39 Willms Ranch Pit - Ohe Sand and Gravel
ARA-43 Schmidt Pit - Western Stone Products, Inc.
ARA-45 Landmark Pit - Western Stone Products, Inc.
ARA-46 Warner Pit - Western Stone Products, Inc.
Hickman Pit - Western Stone Products, Inc.
ARA-47 Waterford Site - George Reed, Inc.
Waterford Pit (western portion) - M.J. Ruddy & Son, Inc.
ARA-48 Waterford Pit (eastern portion) - M.J. Ruddy & Son, Inc.
ARA-49 Waterford Pit - 7/11 Materials, Inc.
ARA-50 Roberts Ferry Pit - 7/11 Materials, Inc.
La Grange Pit - M.J. Ruddy & Son, Inc.
Cree Ranch Pit - Western Stone Products, Inc.
ARA-54 La Grange Pit - Stanislaus County Dept. of Public Works
ARA-55 Sarah Reeves Pit - George Reed, Inc.

Three Aggregate Resource Areas are identified as **Highly Significant** because they contain more than 18 million tons of concrete-grade construction aggregate resources. These ARAs total 3.03 square miles which represents about 0.2 percent of the total land area in Stanislaus County. Thirteen Aggregate Resource Areas are identified as **Significant** because they contain between 1.8 million tons and 18 million tons of construction aggregate resources. These ARAs total 3.36 square miles, which represents about 0.22 percent of the total land area in Stanislaus County. An additional 22 areas are labeled (S) on Table 6. These 22 areas do not meet the threshold value of 1.8 million tons and must be

included with nearby ARAs identified as **Significant**. Estimated total concrete-grade aggregate resources for all 55 ARAs are approximately 540 million tons.

LIFE EXPECTANCY OF CONSTRUCTION AGGREGATE RESERVES

There are currently 18 permitted commercial and two non-commercial aggregate mining operations within the study area tha have a combined concrete-grade aggregate reserve base of 27,700,000 tons. Annual aggregate production in Stanislaus Count has increased from approximately 770,000 tons in 1960 to 2,583,000 tons in 1991. An estimated 25 percent of the aggregate consumed in Stanislaus County in 1991 was imported from aggregat producing areas in adjacent counties.

The State of California (California Department of Finance, 1992) projects the population of Stanislaus County from 1990 to the year 2020 will increase by 223 percent. A continued population growth at the same rate to the year 2040 will increas the 1990 population by 326 percent. With increased population pressures, there is an associated risk of losing aggregate resource areas to encroaching urbanization.

At the current rate of production, the permitted reserves o concrete-grade aggregate in Stanislaus County will be depleted b the year 2002, eight years from the time of this study. The expected longevity of these reserves is based on the assumption that mining will continue to be permitted until the reserves are depleted. To significantly increase the aggregate reserve base o Stanislaus County, new mines should be given serious consideration by aggregate producers, local planners, and decision-makers. Planning for new mine sites can minimize incompatible adjacent land uses and can more easily mitigate environmental impacts.

INDUSTRIAL MINERAL RESOURCES

Industrial minerals mined in Stanislaus County and classified during the present study include kaolinitic clay, diatomite, magnesite, quartz (silica), and dimension stone. Thos not mined include bentonitic clay, specialty sand, and expansibl shale.

In the eastern part of the county, near Cooperstown and La Grange, one area was classified MRZ-2a for kaolinitic clay, thre were classified MRZ-2b for kaolinitic clay, and two more were classified MRZ-2b for quartz-rich specialty sand. All of these are underlain by strata of the Ione Formation, which is classified otherwise as MRZ-3a or MRZ-3b from Knights Ferry to La Grange. We conclude that this formation is host to many more

deposits of both commodities than is apparent at the ground surface, and that additional exploration in the areas classified as MRZ-3a and MRZ-3b will reveal several of these deposits. For example, indurated sandstone likely covers concealed horizons of claystone in many of the areas. Also in this region, the Ione hosts variegated, well-cemented sandstone that might be exploited in the future for applications in the building and landscaping industries. Deposits of slate, also used as dimension stone, are present in the metamorphic terrane around La Grange. The region from Knights Ferry to La Grange is thus a favorable geologic environment for industrial minerals that could be of important future economic benefit to the county.

In the Coast Ranges west of Newman, two areas have been classified as MRZ-2b, one for diatomite and the other for specialty sand. The diatomite is in the Kreyenhagen Shale, which is extensive in this region. Additional exploration could reveal substantial reserves of this low-grade material, which has had many industrial applications in the past. As with the Ione Formation described above, exploitation of this resource could be an important stimulus to the local economy. Within the same general area, the specialty sand is associated with the Poverty Flat Sandstone, a formation exposed only in Stanislaus County. In addition, within this unit is a horizon of kaolinitic clay, which might be of commercial interest depending on its extent. Also in this region, the Tesla Formation, which was classified MRZ-3a for specialty sand, has a few known horizons of quartzose sandstone that may be of future commercial interest.

In Del Puerto Canyon, a quartz-vein complex was classified as MRZ-2b. It could be a low-volume, high-value source of silica for special applications. Alternatively, this deposit is a local scientific and scenic curiosity that might best be left intact.

Two of the three other industrial minerals classified, magnesite and expansible shale, would require special circumstances for exploitation. The magnesite of the Coast Ranges may be valuable as a high-brightness, high-purity material, although reserves appear to be largely depleted in known deposits, and exploration for and mining of new deposits would be very difficult. The expansible shale, although abundant in the Coast Ranges, would need to exhibit special physical properties that could compete favorably with already-established resources outside the county. Regarding bentonitic clay, its presence in the Valley Springs Formation is poorly established, yet this rock unit is a favorable geologic environment for the occurrence of such clay.

METALLIC MINERAL RESOURCES

Classification of metallic mineral resources in Stanislau County falls under four genetic classes of mineral deposits. These include hydrothermal, magmatic segregation, volcanogenic and volcanogenic-sedimentary. No area in the county was classified higher than MRZ-3a for any of these categories. In other words, for the near future, metallic resources have the least potential of the three major categories of mineral resources described here. This conclusion reflects not so much lack of ore deposits, but rather the economics that control mining of them.

Within the Coast Ranges, there is potential for significa deposits of mercury and gold formed by hydrothermal processes under epithermal conditions; an important result of this study was the detection of low-grade gold at one mercury mine. Also this area are known and potential deposits of manganese and chromite, some of which may be significant. Nonetheless, altho considered strategic minerals by the Federal government, these two commodities are expected to be of economic interest only during national emergencies.

In the Sierra Nevada foothills, there are no known lode deposits of precious metals (gold and silver) formed by hydrothermal processes, yet the geologic environment is favora for such deposits. Similarly, there is potential for significa deposits of precious and base metals (copper, lead, and zinc) formed by volcanogenic processes associated with the metamorphi terrane of the foothills.

Regarding placer gold, the concentrations of this commodit in such deposits are typically extremely low. It thus requires the removal and processing of substantial amounts of sedimenta materials to be commercially successful. We do not believe that society today will accept the disturbance of large tracts of ground, particularly along rivers, for the mining of placer gol alone. Such gold has been extracted as a by-product of aggregat mining in the county for many years. This situation is expected to continue in the future.

ACKNOWLEDGMENTS

A complex study of this type requires the help of many people, many of whom may not realize how important their contributions are. We thank everyone who has assisted and supported our work, especially those folks listed below:

- Numerous property owners in the county, without the cooperation of whom we would not have had access for the essential field work in this study.

- All of the aggregate-mine operators in Stanislaus County for their assistance and provision of proprietary data used in our study of the aggregate resources of the county.

- Linda Falasco of the Central Valley Rock, Sand and Gravel Association for organizing the cooperation of the operators, Jim Kraft of Kraftile Company for his help on the clay deposits of eastern Stanislaus County, and Richard Hutchens of H.C. Muddox for his help on the diatomite deposits near Newman.

- Clark Blake, Russ Evarts, and Jay Noller for sharing their ideas and observations on the geology of the Coast Ranges.

- Carl Mazzo of Exxon Coal and Minerals Company for providing us with logs of drill-holes in the Cooperstown area.

- Forrest Bacon, Alan Bartow, Brett Cox, Abbas Kimyai, and Peter Schiffman for discussions of various aspects of the geology of the county.

- Kay Robinson for access to Henry W. Coe State Park, Russ Robinson for help at the California Well Sample Repository, Guy Romito for help in soils mapping, and Mike Dunlap for assistance in the use of a scanning electron microscope at the University of California, Davis.

- Bob Kachel and Chip Sellers at the Stanislaus County Department of Planning and Community Development for their cooperation and patience during the project.

- Fellow employees in other government agencies including the California Department of Forestry and Fire Protection, the Modesto and Turlock Irrigation Districts, and the U.S. Army Corps of Engineers for information.

We especially acknowledge our fellow employees within the Division of Mines and Geology, including Joy Sullivan, Ed Foster, Jim Williams, and Debbie Maldonado for perseverance in drafting; Peggy Bayliss and Virginia Williams for typing; Sylvia Bender-

Lamb for library assistance; and Bob Hill, John Alfors, and Rus Miller for their reviews of the manuscript and their patience a flexibility in allowing us to complete this project in the way originally intended.

Finally, we dedicate this report to John Alfors, a perceptive geologist and dedicated civil servant, upon his retirement from the Division of Mines and Geology.

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APPENDIX A

Mines and Prospects in Stanislaus County

EXPLANATION FOR APPENDIX A

This appendix lists known mines and prospects within the study area, which includes all of Stanislaus County and a small portion of San Joaquin County, where the Stanislaus River forms the common boundary between the two. Not included are inactive properties mined for construction fill or properties outside the study area. Comments are based on information obtained from field visits to all important mines and prospects, as well as from the references cited in Appendix A.

All numbered properties are listed within three groups according to which plate, 8A, 8B, or 8C, on which the properties are shown. Properties with **map numbers 1 through 99** are on **Plate 8A**, those with **map numbers 100-105** are on **Plate 8B**, and those with **map numbers 106-211** are on **Plate 8C**. Within each group, properties are listed alphabetically, first by **commodity** and then by **property name** within each corresponding commodity listing. The locations of symbols for aggregate operations and particular gold mines (dredge and placer operations) are approximate, as they serve to locate active or historic operations that cover relatively large areas.

Some properties have reported locations that are ambiguous, but are of historic interest. These properties were not plotted on Plates 8A, 8B, and 8C, because their locations could not be determined accurately. Although they are included in Appendix A, some potential future aggregate mining sites are not shown on Plates 8A, 8B, or 8C, because mining had not commenced or because mining permits had not been obtained as of January 1, 1993, the final date for data acquisition for this project.

Regarding properties mined for construction aggregate prior to 1970, locations and dates of operations are approximate. For those mined prior to 1930, little information is available.

GROUP **PAGE**

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Mines and Prospects (Plate 8C).....A20

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
16	Del Puerto Creek Pit/unknown operator	Patterson Sec 15, T5S, R7E	Base aggregate	Local farmers report this site was mined for aggregate during the early 1950s. Aggregate from this site was probably used in the construction of the nearby Delta-Mendota canal. Pit depth was in excess of 30 feet. Sand and gravel at this site is poorly graded Holocene Del Puerto Creek alluvium. The abandoned pit is mostly filled with water. Maximum sized boulders are about 8 inches in diameter. Cobble- and boulder-sized clasts are commonly coated with calcium carbonate cemented coatings. The excavated area is about 550 feet by 250 feet.
93	Orestimba Creek Pit/Toni Francisco Co.	Newman Secs 2, 3, T7S, R8E	Base aggregate	The Tony Francisco Co. mined sand and gravel along this section of the active Orestimba Creek channel during the 1940s. The material was predominately sand sized with lesser amounts of small gravel. This site was largely depleted of the coarse-size aggregate fraction by the mid 1950s.
92	Orestimba Creek Pit/J.C Scanlon Co.	Newman Sec 10, T7S, R8E	Base aggregate	J.C. Scanlon Co. mined sand and gravel from the active Orestimba Creek channel during the 1940s. The mined material was chiefly sand-sized material with lesser amounts of gravel.
14	Zacharias Road North Pit/Lee White	Patterson Sec 17, T5S, R7E	Base aggregate	This site is located at the west end of Zacharias Road within the elevated western-most portion of the Del Puerto fan apron. Alluvium at this site has been intermittently mined for base aggregate since 1980 for use in local road construction. Excavations at this site extend for approximately 900 feet along the west side of Zacharias Road, and cut about 100-150 feet into the hill slope.
15	Zacharias Road South Pit/Lee White	Patterson Sec 21, T5S, R7E	Base aggregate	This site is about 500 feet southwest of the Zacharias Road North Pit. Base aggregate from this pit has been intermittently excavated since 1980 for use in local roads. Excavations at this site extend for about 700 feet along the west side of Zacharias Road and vary from 25-50 feet vertically along the base of steep hill slopes within the Del Puerto fan apron.
99	Garzas Creek Pit/County of Merced	Howard Ranch Sec 17, T8S, R8E	Concrete aggregate	This 30-acre site has been mined since 1981 by the Merced County Department of Roads. Depth of mined sand and gravel is 10-15 feet. Aggregate is Holocene alluvium of the Garzas Creek floodplain. Maximum sized clasts are 6 inches in diameter.
90	Orestimba Creek Pit/Frank B. Marks & Sons, Inc.	Orestimba Peak Sec 19, T7S, R8E	Concrete aggregate	This site is within the Orestimba Creek alluvial floodplain and has been mined for aggregate since 1980. The material is Holocene alluvium. Maximum sized clasts are 10 inches in diameter.

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
91	Stuhr Road Pit/Frank B. Marks & Sons, Inc.	Newman Secs 9, 10, T7S, R8E	Concrete aggregate	The Marks family has mined the Orestimba Creek floodplain intermittently since 1906. Year-round mining began in 1924 and has been continuous since then. The aggregate is Holocene alluvium derived from the Coast Ranges and is composed of clasts from the Panoche Formation, Moreno Formation, Tesla Formation, Kreyenhagen Shale, Poverty Flat Sandstone, Valley Springs Formation, and Franciscan Complex. Dominant clast lithology includes metagraywacke, chert, greenstone, schist, metavolcanic rocks, and vein quartz. Aggregate thickness is 100 feet or more. Maximum sized clasts are 8 inches in diameter.
64	Adobe Canyon Mine (east workings)	Mt. Boardman SW4, Sec 14, T6S, R5E	Chromite	Short tunnel driven to intersect flat sheets of ore in dunite-wehrlite unit of Coast Range Ophiolite. Ore appears to be related to an east-west-trending fault. Production probably minor. [Hawkes and others (1942)]
63	Adobe Canyon Mine (main workings)	Mt. Boardman SW4, Sec 14, T6S, R5E	Chromite	Several open cuts, tunnels, and a glory hole in dunite-wehrlite unit of Coast Range Ophiolite. Both massive and disseminated chromite are distributed as bands and layers in the ultramafic rock. Mining continued into the 1950s, but ceased in 1958 when government price supports ended. At one time, ore was trammed about 1/4 mile from these workings to a concentrating mill at the confluence of Adobe Creek and Del Puerto Creek. Reported minimum production of 500 tons, with possible 350 tons of low-grade (10% chromite) reserves remaining in the glory hole; determination of reserves is difficult because of the irregular distribution and variable grade of ore. [Bradley and others (1918), Charles (1947), Hawkes and others (1942), Walker and Griggs (1953)]
28	Black Bart Mine	Mt. Boardman NW4, Sec 16, T6S, R5E	Chromite	Main producer in Hideout Canyon area. Consists of several open cuts, several adits, and an inclined shaft. The shaft is still accessible and exposes ore near the entrance; this location is not the original surface entrance, which appears to have been destroyed by a later open cut. Ore sampled here assayed at 23.5% chromium (Appendix B). Reportedly less than 500 tons of ore produced before 1950s, mainly from a 90-foot-long zone about 1-6 feet wide. Production in 1957 was estimated at 320 tons of milling ore, which yielded 120 tons of concentrates. Reserves estimated to be 1,500-2,000 tons of unknown grade. Ore bodies in contact zone between dunite-wehrlite unit and harzburgite unit of Coast Range Ophiolite. [Hawkes and others (1942), Charles (1947), Walker and Griggs (1953)]
49	Black Bear Mine	Mt. Boardman NW4, Sec 22, T6S, R5E	Chromite	Workings consist of several tunnels drifted along an east-west-trending mineralized zone about 200 feet long. The ore is present as streaks and lenses of high-grade chromite within the dunite-wehrlite unit of the Coast Range Ophiolite. Reported production is about 350 tons of chromite ore, with little or no reserves left. [Hawkes and others (1942), Charles (1947), Walker and Griggs (1953)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
35	Chrome Camp Mine	Mt. Boardman SW4, Sec 11, T6S, R5E	Chromite	Chromite mined from two sites on both sides of ridge where serpentinite is in contact with Franciscan Complex. Workings comprised open cuts and tunnels. An estimated 930 tons of ore produced, with no reserves in sight. Serpentinite is mapped as part of harzburgite unit of Coast Range Ophiolite, but ore deposit may be in a small pod of dunite along fault contact between harzburgite unit and Franciscan Complex. Location of mine is in some dispute. [Charles (1947), Hawkes and others (1942), Walker and Griggs (1953)]
30	East Black Bart Mine	Mt. Boardman NW4, Sec 16, T6S, R5E	Chromite	Small underground mine within dunite-wehrlite unit of Coast Range Ophiolite. Chromite is along an east-west-striking, north-dipping mineralized zone, similar in character to that at Black Bart Mine. [Hawkes and others (1942)]
11	Grummett Mine	Solyo SW4, Sec 8, T5S, R6E	Chromite	Small deposit in tectonic block of serpentinite within melange of Franciscan Complex. Ore forms irregular masses within serpentinite, which is sheared and crushed. Ore body opened up for a length of 40 feet by open cut, which is extended at depth by a shaft of unknown dimensions. Shaft broadens at bottom, possibly into drifts. Rock on small dump near open cut is hydrothermally altered with iron oxide, veining, and open cavities indicative of epithermal conditions. Shows anomalous mercury mineralization (Appendix B). About 100 tons of chromite ore reportedly shipped during World War I. [Charles (1947)]
45	Lucky Girl Mine	Mt. Boardman NW4, Sec 22, T6S, R5E	Chromite	Several small open cuts and adits along a shear zone that trends N80°E in dunite-wehrlite unit of Coast Range Ophiolite. Ore is present as lenses and pods of massive and disseminated chromite. An estimated 150 tons of ore produced, with 300 tons of reserves remaining. [Bradley and others (1918), Charles (1947), Hawkes and others (1942), Walker and Griggs (1953)]
51	Number 5 Mine	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small body of disseminated chromite in dunite-wehrlite unit of Coast Range Ophiolite. About 250 tons of ore reportedly mined from two open pits at this site. Apparently little remaining ore visible at surface. Part of a west-northwest-trending mineralized zone that crosses Del Puerto Creek southeast of the mine. [Hawkes and others (1942)]
53	Number 5 Mine	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small open cut in ore body that trends west-northwest and dips 70°NE. Deposit is in dunite-wehrlite unit of Coast Range Ophiolite. Part of a west-northwest-trending mineralized zone that crosses Del Puerto Creek northwest of the mine. [Hawkes and others (1942)]
54	Number 5 Mine	Mt. Boardman SW4, Sec 14, T6S, R5E	Chromite	Two small open pits in disseminated chromite along a zone from which about 500 tons of ore were reportedly mined. Deposits are in form of linear pods within dunite-wehrlite unit of Coast Range Ophiolite. Part of a west-northwest-trending mineralized zone that crosses Del Puerto Creek northwest of the mine. [Hawkes and others (1942)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
55	Number 5 Mine	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small open cut and east-trending tunnel in disseminated chromite along a zone from which about 500 tons of ore were reportedly mined. Deposits are in form of linear pods within dunite-wehrlite unit of Coast Range Ophiolite. Part of a west-northwest-trending mineralized zone that crosses Del Puerto Creek northwest of the mine. [Hawkes and others (1942)]
52	Number 5 Mine (main workings)	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Site of main production from Number 5 group of mines. Total production estimated to be over 1,200 tons of massive chromite from a flat-lying ledge, which ranks it the main producer in Stanislaus County. Site of ore bodies subsequently caved in and slid into the canyon; today the site has been excavated well back from the highway. Another ore body of disseminated chromite was directly under the massive ledge and produced about 270 tons of chromium oxide concentrates. The deposits are in the dunite-wehrlite unit of the Coast Range Ophiolite. Reserves have not been estimated because workings are caved and no ore of importance was observed in outcrop. The massive ore described above was exhausted by 1918, and some mining was done in the 1940s and possibly 1950s. [Hawkes and others (1942), Bradley and others (1918), Charles (1947), Walker and Griggs (1953)]
27	Prospect	Mt. Boardman NE4, Sec 17, T6S, R5E	Chromite	Small workings within dunite of Coast Range Ophiolite. [Hawkes and others (1942)]
29	Prospect	Mt. Boardman NW4, Sec 16, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
31	Prospect	Mt. Boardman NE4, Sec 16, T6S, R5E	Chromite	Small workings in area mapped as harzburgite unit of Coast Range Ophiolite. May be in small unmapped body of dunite. [Hawkes and others (1942)]
39	Prospect	Mt. Boardman SE4, Sec 16, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. Dump visible from Del Puerto Canyon Road. [Hawkes and others (1942)]
41	Prospect	Mt. Boardman NE4, Sec 21, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
43	Prospect	Mt. Boardman SW4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
44	Prospect	Mt. Boardman SW4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
46	Prospect	Mt. Boardman NW4, Sec 22, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
47	Prospect	Mt. Boardman NW4, Sec 22, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
48	Prospect	Mt. Boardman NW4, Sec 22, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
50	Prospect	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
56	Prospect	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
57	Prospect	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
58	Prospect	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
59	Prospect	Mt. Boardman SE4, Sec 15, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
60	Prospect	Mt. Boardman NE4, Sec 22, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
61	Prospect	Mt. Boardman NE4, Sec 22, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
62	Prospect	Mt. Boardman NW4, Sec 23, T6S, R5E	Chromite	Shown as prospect symbol on Mt. Boardman 7.5-minute quadrangle. Plots in dunite-wehrlite unit of Coast Range Ophiolite. Inferred to be chromite prospect. [Mt. Boardman 7.5-minute quadrangle]

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
65	Prospect	Mt. Boardman NW4, Sec 23, T6S, R5E	Chromite	Small workings in dunite-wehrlite unit of Coast Range Ophiolite. [Hawkes and others (1942)]
81	Base Materials Pit	Orestimba Peak SW4, Sec 1, T7S, R7E	Diatomite	Open pit in Kreyenhagen Shale operated by Base Materials Company at least until 1950. Disturbed area is about 300 feet by 500 feet, with one west-facing cut about 10-15 feet high. Diatomite dips gently east and is cut by sandstone dikes. Diatomite used as filler in paint, paper, insecticide, and fertilizer and as absorbent for oil and in poultry litter. Specific gravity reported to be 2.38 compared to 1.83 for pure diatomite. See Appendix B, STC-40c. H.C. Muddox Company may have mined here in last 10-15 years. [Davis (1951), Booth (1950), Laizure (1925)]
88	Cro-Diatomite Pit	Orestimba Peak SE4, Sec 12, T7S, R7E	Diatomite	Open pit in Kreyenhagen Shale operated by Cro-Diatomite Company up to 1950. Bulldozer tracks in vicinity indicate more recent activity possibly by H.C. Muddox Company. Main pit is near top of hill and is about 250 feet by 100 feet; pit face is about 15 feet high. Diatomite is cut by sandstone dikes. Reportedly used as pozzolanic additive in cement. A smaller pit (20 feet by 60 feet) is a few hundred feet southeast of the main pit. [Davis (1951), Booth (1950), Charles (1947)]
89	Cro-Diatomite Pit	Orestimba Creek SE4, Sec 12, T7S, R7E	Diatomite	Open pit in Kreyenhagen Shale operated by Cro-Diatomite Company up to 1950. Pit is near top of hill; area of disturbance is about 200 feet by 250 feet with a 5-10 foot face. Diatomite is cut by sandstone dikes. Reportedly used as pozzolanic additive in cement. Concrete foundation is downslope to north. H.C. Muddox Company may have mined here in the last 10-15 years. [Davis (1951), Booth (1950), Charles (1947)]
82	Muddox Pit	Orestimba Peak NW4, Sec 12, T7S, R7E	Diatomite	Scalped area on summit of small hill composed of Kreyenhagen Shale. Mined by H.C. Muddox for flue pipe in fireplaces.
83	Muddox Pit	Orestimba Peak NW4, Sec 12, T7S, R7E	Diatomite	Scalped area on summit of small hill composed of Kreyenhagen Shale. Mined by H.C. Muddox for flue pipe in fireplaces.
84	Muddox Pit	Orestimba Peak NW4, Sec 12, T7S, R7E	Diatomite	Scalped area on summit of small hill composed of Kreyenhagen Shale. Mined by H.C. Muddox for flue pipe in fireplaces.
85	Muddox Pit	Orestimba Peak SE4, Sec 12, T7S, R7E	Diatomite	Scalped area on summit of small hill composed of Kreyenhagen Shale. Mined by H.C. Muddox for flue pipe in fireplaces.

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
86	Muddox Pit	Orestimba Peak NE4, Sec 12, T7S, R7E	Diatomite	Scalped area on summit of small hill composed of Kreyenhagen Shale. Mined by H.C. Muddox for flue pipe in fireplaces.
87	Muddox Pit	Orestimba Peak NE4, Sec 12, T7S, R7E	Diatomite	Large open pit cut into summit of hill composed of Kreyenhagen Shale. Dimensions about 150 feet by 300 feet, with a pit face about 10-15 feet high maximum. Exposes gently dipping diatomite cut by sandstone dikes and small veinlets of gypsum. Strata of light-colored diatomite alternate with pinkish-brown, clay-rich horizons less than one foot thick. See Appendix B, STC-45a.
98	Bald Eagle Mine (Howard Cattle Company)	Crevison Peak NE4, Sec 5, T9S, R7E	Magnesite	Adjoining workings originally operated separately from property in Section 32. Part of large mass of serpentinite impregnated with magnesite. Site today is marked by extensive dumps from underground workings. [Bradley (1925), Laizure (1925)]
96	Bald Eagle Mine (northwest workings)	Crevison Peak, SW4, Sec 32, T8S, R7E	Magnesite	Workings developed in northwest extension of main ore body mined at original workings. Most are northerly trending adits that intersect tunnels drifted along the main ore body, which is inclined. Ore was trammed to calcining plant. [Perry and Kirwan (1942)]
97	Bald Eagle Mine (original workings)	Crevison Peak SE4, Sec 32, T8S, R7E	Magnesite	The most productive magnesite mine in Stanislaus County. Originally operated during World War I and briefly during the 1920s. Main development and production was from 1930-1944, which ended when the ore body was exhausted. Magnesite was in form of amorphous nodules and small pellets that comprised a bed, which ranged up to 30 feet in thickness. This bed dipped to the south and was within a mass of serpentinite breccia. The breccia is probably a landslide, active before, during, and after the magnesite was deposited in open channels by hydrothermal solutions. At this site are the original tunnel and drifts, in addition to the crusher and calcining plants operated by Westvaco Chlorine Products Corporation. Total production from this mine is unknown, but size of dumps indicate it was probably more than the Red Mountain Mine. Reserves are assumed to be negligible. [Perry and Kirwan (1942), Boalich (1921), Laizure (1925), Bradley (1925), Charles (1947)]
76	Promberger Prospect	Copper Mountain SW4, Sec 4, T6S, R6E	Magnesite	Small adit in magnesite-bearing, intensely sheared serpentinite. Tunnel about 50 feet long and trends north-northeast. Magnesite is in veinlets and nodules. Probably one of several tunnels reported on a mineralized zone estimated at 700-1,000 feet wide over a distance of nearly 2 miles. Longest tunnel reported to be 100 feet long. [Charles (1947)]
21	Prospect	Mt. Boardman NE4, Sec 18, T6S, R5E	Magnesite	Shown as small open cut on northwest-trending vein of magnesite in harzburgite unit of Coast Range Ophiolite. Listed as one of "North prospects." Exposed length of vein is about 100 feet. [Bodenlos (1950)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
22	Prospect	Mt. Boardman NE4, Sec 18, T6S, R5E	Magnesite	Shown as open cut on north-northwest-trending vein of magnesite in harzburgite unit of Coast Range Ophiolite. Listed as "White Queen Vein" on Chance No. 3 Claim (part of Fenster Prospect?). Exposed length of vein about 300 feet. No known production, but excavation suggests the workings may have been a small mine rather than a prospect. [Bodenlos (1950)]
72	Prospect	Copper Mountain NE4, Sec 8, T6S, R6E	Magnesite	Small open cut/adit (length about 20 feet) in intensely sheared serpentinite of the Jcus unit (Plate 1A). Magnesite is in form of small veinlets, encrustations, and replacement nodules in the serpentinite. No steeply dipping wide veins observed as at Red Mountain.
75	Prospect	Copper Mountain NE4, Sec 8, T6S, R6E	Magnesite	Small adit driven into magnesite-bearing serpentinite. Tunnel is inclined at portal then flattens for unknown distance. Serpentinite in immediate area is highly sheared and riddled with small veinlets and nodules of magnesite.
95	Prospect	Crevison Peak NE4, Sec 30, T8S, R7E	Magnesite	Quadrangle map shows 4 northeast-trending tunnels. Area is mapped as serpentinite. Assumed commodity is magnesite.
23	Red Mountain Mine	Mt. Boardman NW4, Sec 17, T6S, R5E	Magnesite	Northernmost workings of mine. Probably site of original quarry, which was run along surface exposure of Main Vein. This locality has been mined by both open cut and underground stoping to surface from upper (2400) and lower (2200) levels. Excellent exposures of anastomosing shears in harzburgite unit of Coast Range Ophiolite; shears show some movement after emplacement of magnesite. Magnesite emplaced as fissure-fillings and as replacement bodies (nodules and small pellets). [Bodenlos (1950)]
25	Red Mountain Mine	Mt. Boardman NW4, Sec 17, T6S, R5E	Magnesite	Southernmost workings of mine. This portion of Main Vein has been worked by both open cuts, an adit (2485 level), and stoping from the upper (2400) and lower (2200) levels. Width of vein averaged 2-5 feet. [Bodenlos (1950)]
26	Red Mountain Mine (lower tunnel)	Mt. Boardman NW4, Sec 17, T6S, R5E	Magnesite	Portal of adit of lower (2200) level. Tunnel estimated by projection to be about 800 feet long on a nearly east-west trend. Appears to be caved, yet abundant water drains from entrance. All parts of Main Vein mined or explored from drift off this tunnel. [Bodenlos (1950), Charles (1947)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
24	Red Mountain Mine (upper tunnel)	Mt. Boardman NW4, Sec 17, T6S, R5E	Magnesite	Portal of adit of upper (2400) level. This tunnel leads to drift along main ore body. Most production was from stoping associated with this level. Magnesite is present as veins and replacement bodies (nodules and pellets) within a large shear zone (Main Vein) in harzburgite unit of Coast Range Ophiolite. A smaller ore body (Columbia Vein) is 300 feet west of Main Vein. Main vein was 870 feet long, 370 feet in depth, with a north-northwest strike and steep dip to southwest; ore zone was as much as 60 feet wide. Reportedly produced 70,000-140,000 tons before operations ceased in 1942. Reserves are probably less than 50,000 tons. Chemical analysis indicates high purity material of about 98% $MgCO_3$ (Appendix B). Tunnel is caved at portal. [Bodenlos (1950), Charles (1947), Laizure (1925), Bradley (1925), U.S. Bureau of Mines (1943)]
40	Black Bolt Prospect	Mt. Boardman NE4, Sec 21, T6S, R5E	Manganese	Small ore body explored by 7-foot shaft. Manganese oxide is present in disseminated form and as small pockets in massive chert. Chert mass appears to be a small (25-foot diameter) tectonic block or lens within graywacke sandstone of Franciscan Complex. [Trask and others (1950, no. 1), Jenkins and others (1943)]
34	Black Mike Prospect	Mt. Boardman NW4, Sec 14, T6S, R5E	Manganese	Low-grade deposit prospected by trench and small adit. Manganese oxide ore in massive and thin-bedded chert of Franciscan Complex. Some indication in excavation that ore body may widen with depth. Perhaps 100-150 tons of ore reported to be exposed. [Trask and others (1950, no. 2), Jenkins and others (1943), Volin and others (1956)]
12	Brinkerhoffer Mine	Copper Mountain SE4, Sec 18, T5S, R6E	Manganese	Several adits and open cuts following a manganese oxide body within tightly folded thin-bedded and massive cherts. Exposed ore body is reported to be about 100 feet long and is highly siliceous. Ore shipped probably amounts to less than a few hundred tons. [Trask and others (1950, no. 3), Jenkins and others (1943)]
5	Buckeye Mine (north workings)	Lone Tree Creek SE4, Sec 3, T5S, R5E	Manganese	The most productive manganese mine in the county and possibly the second most productive in California, behind the Ladd Mine in San Joaquin County. Workings began as an open cut on an outcrop of high-grade manganese oxide ore interbedded with massive and thin-bedded chert of Franciscan Complex. Most of ore was removed through various adits and tunnels, with stoping reaching the surface at the original open cut. Ore body is contorted in places, although general attitude was east-west strike with northerly dip. Ore consisted of secondary oxides to about the 1900-foot level, and primary rhodochrosite, hausmannite, and manganese silicates below that level. Ore body averaged 8 feet in thickness, was 170 feet long, and extended 225 feet down dip. It was reportedly largely mined out by 1944 when operations ceased. Production was nearly 26,000 tons of high-grade ore averaging 42% manganese. There may be several thousand tons of low-grade ore remaining. [Trask and others (1950, no. 4), Jenkins and others (1943), Volin and Matson (1949), Huebner and Flohr (1990), Bradley and others (1918), Trengove (1960), Charles (1947)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
6	Buckeye Mine (south workings)	Lone Tree Creek SE4, Sec 3, T5S, R5E	Manganese	Workings consist of two development levels accessed by west-trending adits. Ore body mainly black manganese oxide, with some manganese carbonate at depth. The ore from the upper level to the surface has been mined out. Low-grade ore remains on margins of the original ore body, which was interbedded with massive and thin-bedded chert of the Franciscan Complex. Reported production from these workings is 3,800 tons. Reserves are probably minor. [Trask and others (1950, no. 4), Volin and Matson (1949)]
33	Claim 14 Prospect	Mt. Boardman NE4, Sec 15, T6S, R5E	Manganese	Two exposures of siliceous manganese oxide ore about 130 feet apart. Explored by open cut and several trenches. Deposit is in massive chert of Franciscan Complex and is reported to be of "no consequence." [Trask and others (1950, no. 5), Jenkins and others (1943), Volin and others (1956)]
70	Gerber Mine	Mt. Boardman SE4, Sec 27, T6S, R5E	Manganese	Workings in this area comprise a few open cuts and adits. Ore appears to be both low- and high-grade siliceous manganese oxide, which may exceed 500 tons in reserves. Associated with massive and thin-bedded chert of Franciscan Complex. Production unknown because it was combined in statistics for nearby Jones Mine. [Trask and others (1950, no. 9), Jenkins and others (1943)]
9	Grummett-Knox Mine	Solyo SE4, Sec 6, T5S, R6E	Manganese	Several small open cuts and adits in siliceous manganese oxide associated with massive and thin-bedded chert of Franciscan Complex. Deposit generally low-grade. Production probably less than 150 tons. [Trask and others (1950, no. 11, Jenkins and others (1943)]
73	Hammond(?) Prospect	Copper Mountain SE4, Sec 8, T6S, R6E	Manganese	Interpreted to be location number 14 of Trask and others (1950). Small workings on both sides of steep gully. On south side is small open cut along minor manganese oxide horizon in strongly brecciated and recrystallized chert. On north side is a small adit driven in Lotta Creek Tuff presumably to intersect manganiferous chert. Mineralization appears to be minor compared to typical deposits in Franciscan Complex. [Trask and others (1950, no. 14(?), Evarts (1978), Jenkins and others (1943)]
1	Liberty Mine	Solyo SW4, Sec 36, T4S, R5E	Manganese	The second most productive manganese mine in the county. Workings are in two areas along a northwest-trending spur. Main workings consist of an adit with drifts following the ore zone. Ore has been stoped to surface near portal of adit. Small septum shows vertical bed of manganese ore interbedded with massive and thin-bedded chert of Franciscan Complex. Western workings consist of open cuts and an adit, which connects with main adit. Excellent exposure here of manganese ore body interbedded with massive and thin-bedded chert. A third adit is north of the main adit; it exposes only one minor manganese horizon in a sequence of thin-bedded chert. Reported production of nearly 4,000 tons. May be nearly 1,000 tons of reserves. Property reportedly abandoned in 1944. Assay of high-grade ore at western workings showed 53% manganese. [Trask and others (1950, no. 16), Jenkins and others (1943), Charles (1947), Trengove (1960)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
32	Lookout Prospect	Mt. Boardman NE4, Sec 15, T6S, R5E	Manganese	Siliceous and massive manganese oxide ore explored by five open cuts and two trenches along a strike length of about 160 feet. Average width of ore horizon about 1-3 feet, but may be as much as 6 feet. Deposit is in massive chert of Franciscan Complex; bounded by graywacke sandstone on south and north(?), and by serpentinite on east. [Trask and others (1950, no. 17), Jenkins and others (1943), Volin and others (1956)]
74	Magnesia Camp Prospect	Copper Mountain NE4, Sec 8, T6S, R6E	Manganese	Interpreted to be number 18 of Trask and others (1950). On east edge of Del Puerto Canyon Road are exposures of distorted and fractured massive and thin-bedded chert of the Franciscan Complex. Associated with the massive chert are a few irregular horizons of manganese oxide, several inches thick at most. The ore horizon described in the literature may have been removed by subsequent road construction. [Trask and others (1950, no. 18?), Jenkins and others (1943)]
42	Mary Lou Prospect	Mt. Boardman NE4, Sec 21, T6S, R5E	Manganese	Small ore body of siliceous manganese oxide explored by 5 small trenches and an open cut. Body exposed about 145 feet along strike, but is very narrow and not uniform in grade. Deposit is enclosed in massive chert of Franciscan Complex. [Trask and others (1950, no. 19), Jenkins and others (1943), Volin and others (1956)]
8	Mezzera Mine	Solyo SW4, Sec 6, T5S, R6E	Manganese	Small deposit of manganese oxide apparently interbedded between massive and thin-bedded chert of Franciscan Complex. Ore was almost completely mined out in 1942. Reportedly 140 tons produced. [Trask and others (1950, no. 20), Jenkins and others (1943)]
3	Mine (name unknown)	Solyo SE4, Sec 36, T4S, R5E	Manganese	Many small open cuts and an adit explore one major 10-foot lens and many minor lenses. Main lens strikes northwest and is near vertical in chert of Franciscan Complex. Ore consists of both soft massive and disseminated manganese oxide. May be an extension of ore body in Moran Brothers Mine across ravine to the northwest. Amount of production unknown.
13	Mine (name unknown)	Copper Mountain SW4, Sec 16, T5S, R6E	Manganese	Mine consisting of open cuts and tunnel in massive and thin-bedded chert of Franciscan Complex. Ore is black manganese oxide interbedded with chert. Open cut 50 feet long followed massive chert bed, then continued as 75-foot tunnel. Chert bed has vertical dip here with small amounts of ore remaining. Adjacent to open cut is another open cut that follows the massive chert as it changes strike from northwest to north-northeast. Production unknown, but was probably no more than a few hundred tons.

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
2	Moran Brothers Mine	Solyo SW4, Sec 36, T4S, R5E	Manganese	Several shafts, adits, trenches, and open cuts explore two west-northwest-trending zones of manganese mineralization, which are interbedded with beds of chert and greenstone of the Franciscan Complex. Some of mineralization is reported to be primary manganese carbonate. This property is important because it demonstrates a rare occurrence of manganese ore beds in contact with greenstone. Production was probably about 200 tons. [Trask and others (1950, no. 21), Jenkins and others (1943)]
37	Murmac Mine	Mt. Boardman SW4, Sec 21, T6S, R5E	Manganese	A group of workings in the Black Wonder District along the summit area between Stanislaus County and Santa Clara County. Extensively explored by U.S. Bureau of Mines with trenching, open cuts, and 2 shafts. Consists of various grades of manganese oxide interbedded with massive and thin-bedded chert of Franciscan Complex. Production reported to be at least a few hundred tons from one of the deposits. [Trask and others (1950, described in section about Santa Clara County), Jenkins and others (1943), Volin and others (1956)]
38	Park Mine (Low Gap Mine)	Mt. Boardman SE4, Sec 21, T6S, R5E	Manganese	Three small deposits of low-grade manganese oxide ore explored by a few open cuts and trenches. Part of Black Wonder District along summit area between Stanislaus County and Santa Clara County. Manganese oxide interbedded with massive and thin-bedded chert of Franciscan Complex. Reportedly minor production. [Trask and others (1950, no. 22), Jenkins and others (1943), Volin and others (1956)]
17	Prospect	Mt. Boardman NW4, Sec 28, T5S, R5E	Manganese	Property comprises a caved adit and a 50-foot-long open cut. Not known if any production. Open cut exposes massive light green chert with minor manganese oxide ore; part of Eylar Mountain Terrane of Franciscan Complex. Graywacke exposed along entire length of trail leading from summit of main ridge down to the property.
18	Section 23 Mine	Mt. Boardman SE4, Sec 23, T5S, R5E	Manganese	Small circular-shaped open cut with a caved adit driven southerly from the face of the cut. Small ore body of manganese oxide is exposed in open cut; body is faulted and irregular in shape. Small ore dump mentioned by Trask and others is still present. [Trask and others (1950, no. 23)]
4	Sulphur Gulch Prospect	Lone Tree Creek NW4, Sec 2, T5S, R5E	Manganese	Reportedly prospected in 1918 by means of two open cuts, an adit, and a winze, which discovered only a few tons of low-grade ore. Within Eylar Mountain Terrane of Franciscan Complex. [Trask and others (1950, no. 24), Jenkins and others (1943)]
10	Sunbeam Mine	Lone Tree Creek SE4, Sec 11, T5S, R5E	Manganese	One main open cut and a smaller open cut 200 feet to south, both along steep slope. Main cut exposes both massive and thin-bedded chert, which is contorted. Ore consists of manganese oxide associated with massive chert. Reportedly produced more than 150 tons. Sample of ore assayed at 47.5% Mn (Appendix B). Associated with Oso Broken Formation of Franciscan Complex. [Trask and others (1950, no. 26), Jenkins and others (1943)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
7	Tip Top Mine	Solyo SW4, Sec 1, T5S, R5E	Manganese	One of the most productive manganese mines in the county, this property is in the same belt of extensive chert of the Franciscan Complex (Grummett Broken Formation) in which the Buckeye Mine is situated. Workings consist of open cuts and an adit. Manganese oxide ore of various grades was present in 3 separate lenses interbedded with massive and thin-bedded chert. Remaining reserves of all grades may be a few thousand tons. Reported production here was more than 1,600 tons when operations ceased in 1955. [Trask and others (1950, no. 28), Jenkins and others (1943), Bradley and others (1918), Trengove (1960)]
69	Adobe Valley Mine	Copper Mountain NE4, Sec 24, T6S, R5E	Mercury	Site of recently covered shaft and remains of 50-ton furnace built in 1941. Surrounding rock exposed by dozer cuts shows extensive hydrothermal alteration (argillic, limonitic, hematitic); mainly thin-bedded fine-grained sandstone of Adobe Flat Shale Member of Panoche Formation. Extensive dump material. Cinnabar disseminated as impregnations within pore spaces of sandstone and as coatings on fractures stained with iron oxide. Samples from 5-gallon buckets near furnace site assayed 0.047 ounces/ton gold; also elevated copper, zinc, silver relative to other areas of epithermal mineralization in the county. Mercury determined at 0.6% for these samples also. Country rock is pervasively hydrothermally altered for several hundred feet surrounding the shaft. [Hawkes and others (1942), Charles (1947)]
68	Adobe Valley Mine (main workings)	Copper Mountain NE4, Sec 24, T6S, R5E	Mercury	Extensive underground workings recently sealed by owner of property. Large dumps still remain. Shafts and tunnels followed ore along north-northeast-trending fault. Ore occurs as cinnabar disseminated in faulted sandstone of Adobe Flat Shale Member of Panoche Formation. Dump has abundant sulfide mineralization, particularly pyrite. Two-compartment shaft, constructed in 1880s, reportedly 180 feet deep. Ore locally averaged 7.65 pounds of mercury per ton. Total production unknown, but probably second in county to Phoenix (Summit) Mine. See description for property number 69. [Hawkes and others (1942), Forstner (1903), Charles (1947), Bradley (1918), Watts (1890), Lowell (1915)]
19	Crocker-Winship Prosect (?)	Mt. Boardman NE4, Sec 31, T5S, R5E	Mercury	Interpreted to be mercury prospect shown by Maddock (1964). Locations reported in other literature suggest this site may be the Crocker-Winship property. Some work done about 1913, but property was reportedly never completely developed and no appreciable amount of mercury was ever produced. Location plots in Eylar Mountain Terrane of Franciscan Complex. [Maddock (1964), Charles (1947), Laizure (1925)]

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
80	International Mine	Wilcox Ridge NE4, Sec 28, T7S, R6E	Mercury	Reportedly established about 1880, with minor production. Workings consisted of two tunnels. These may have been covered by recent construction of a road at the site (a few mine timbers on side of road). Site is sheared and brecciated serpentinite in contact with hydrothermally altered graywacke sandstone of Franciscan Complex. Some fragments of silica-carbonate rock observed on what may be remnant of mine dump. Minor impregnations of magnesite locally. Serpentinite is strongly magnetic. [Bradley (1918), Watts (1890), Charles (1947)]
20	Newhall Prospect(?)	Mt. Boardman NW4, Sec 32, T5S, R5E	Mercury	Interpreted to be mercury prospect shown by Maddock (1964). Reportedly never completely developed, with little or no production. Cinnabar reported in sandstone and serpentinite, which are part of Eylar Mountain Terrane of Franciscan Complex. Unverified report of 800-foot wide zone of mineralization. [Maddock (1964), Bradley (1918)]
79	Orestimba Mine	Wilcox Ridge NE4, Sec 28, T7S, R6E	Mercury	Main workings on south bank of Orestimba Creek. Consist of 2-compartment shaft reportedly sunk 75 feet. Shaft is housed within dilapidated building that also contains remains of a retort. Sample analyzed (Appendix B) was from fragments within retort as no dump material remains at site. Shaft is filled with water to about 15-20 feet below shaft collar. Behind shaft collar is an east-west-trending tunnel about 30-40 feet long driven along a hydrothermally altered shear zone. Alteration type is argillic, silicic (quartz veinlets), hematitic, and limonitic. Surrounding graywacke is also altered. Immediately across creek is a northwest-trending tunnel cut about 50-60 feet into a south-dipping 20-foot wide zone of hydrothermally altered graywacke of Franciscan Complex. [Laizure (1925), Charles (1947)]
36	Phoenix Mine (Summit Mine)	Mt. Boardman SE4, Sec 20, T6S, R5E	Mercury	The most productive mercury mine in the county, with a reported 200 flasks produced through 1916. Ore deposit, discovered in 1870s, was worked via several tunnels and a shaft. Ore is cinnabar disseminated in both hydrothermally altered serpentinite (silica-carbonate rock) and sandstone of Franciscan Complex, which are faulted. Tunnels are caved and no longer accessible. Mine symbol shown on quadrangle is location of 50-ton Scott furnace built in 1902-1903; no mine observed at this location. [Watts (1892), Charles (1947), Hawkes and others (1942), Forstner (1903), Bradley (1918), Watts (1890)]
67	Prospect	Copper Mountain NE4, Sec 24, T6S, R5E	Mercury	Site of adit (now covered) and a few small open cuts into cinnabar-bearing sandstone and shale of the Adobe Flat Shale Member of the Panoche Formation. Rock is hydrothermally altered (argillic, limonitic) with disseminated cinnabar. Workings along mineralized faults that trend east-west or northeast and dip northerly. [Hawkes and others (1942)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
78	Prospect	Wilcox Ridge NE4, Sec 31, T7S, R6E	Mercury	Site shown is that observed in field in 1992. Site shown by Maddock (1964) was not found in the field and may be mislocated (?). Observed site is a caved, west-trending adit cut into hydrothermally altered Franciscan Complex. [Maddock (1964)]
71	Winegar Prospect	Mt. Boardman SW4, Sec 25, T6S, R5E	Mercury	Explored by shaft with drifts and a tunnel. Cinnabar is irregularly distributed as fracture fillings in a 5-foot wide fault zone in graywacke of the Franciscan Complex. Fault strikes northwest and dips steeply northeast or southwest depending on segment observed. One segment mined by stope, but ore not shipped as of 1942. [Hawkes and others (1942), Charles (1947), Bradley (1918), Forstner (1903)]
77	Hammond Mine	Copper Mountain SW4, Sec 4, T6S, R6E	Quartz (silica)	Small adit in quartz-calcite vein complex, which strikes northwest and dips steeply northeast; it occupies a fault within the Plutonic Member of the Coast Range Ophiolite. Reported production in 1943 for industrial use. Chemical analyses of quartz range from 98.5% (Appendix B) to over 99% silica (reported elsewhere). Complex continues for at least 1,500 feet to southeast as prominent ledges on flank of ridge above. [Lowell (1915), Laizure (1925), Charles (1947)]
66	Prospect	Mt. Boardman NE4, Sec 24, T6S, R5E	Unknown	Northwest-trending adit (now covered) cut into hydrothermally altered gabbro(?). Dump is tens of feet in dimension. Exploration for mercury(?).
94	Prospect	Mustang Peak NE4, Sec 18, T8S, R6E	Unknown	Large vertical shaft sunk along steep contact between oxidized thin-bedded chert-shale and graywacke(?) of Franciscan Complex. Rock along contact is hydrothermally altered (argillic, hematitic), with iron oxide forming more-resistant irregular masses and veins; contact appears to be pathway for hydrothermal fluids. Dump estimated to be less than 100 cubic yards. Depth of shaft at least 30 feet.
	Vernalis Site/Granite Construction Co.	Solyo Sec 9, T4S, R6E	Concrete aggregate	Granite Construction Company is currently applying for a permit to mine Pleistocene and Holocene alluvium from this site. This site is located in the southwestern portion of the Hospital Creek fan. Nearby areas of the Hospital Creek fan are currently being mined for concrete-grade aggregate. Maximum sized boulders are about 8 inches in diameter. Aggregate thickness is in excess of 100 feet. Clast lithology includes metagraywacke, vein quartz, chert, and basic igneous rock types. (See Plate 2A, Mine Site No. 1 for location of site.)
	Hampton Prospect	Mt. Boardman Sec 16, T6S, R5E	Chromite	Reported to be near center of west half of Section 16 on southwest side of Hideout Creek. Small open cut in disseminated chromite; probably in dunite-wehrlite unit of Coast Range Ophiolite. [Walker and Griggs (1953), Bradley and others (1918)]

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
	Prospect	Patterson Sec 12, T6S, R7E	Coal	Reported to be "small veins of coal" along Salado Creek. May be associated with Tesla Formation. [Laizure (1925), Boalich (1921), Watts (1890), Charles (1947)]
	Prospect	Solyo Sec 12, T5S, R6E	Coal	Reported to be "small veins of coal" in Ingram Canyon, although given location is in Kern Canyon. May be associated with Tesla Formation. [Laizure (1925), Boalich (1921), Watts (1890), Charles (1947)]
	Copper Mountain Prospect	Copper Mountain Sec 15(?), T6S, R6E	Copper	Prospect reportedly located about 1870 on Copper Mountain. Low-grade ore body explored by 90-foot tunnel, but "no definite ledge." Possibly minor disseminated copper mineralization associated with Volcanic Member of Coast Range Ophiolite. [Charles (1947)]
	Fenster Prospect	Mt. Boardman Sec 18(?), T6S, R5E	Magnesite	Reported to be 5 claims adjoining Red Mountain Mine. Outcrop of magnesite on Last Chance Claim reported to be 9-feet thick. May be same as locality number 22 listed above (shown as Chance Claim by Bodenlos, 1950). [Bradley (1925)]
	Prospect	Wilcox Ridge Sec 28, T7S, R6E	Magnesite	Reported occurrences of magnesite only slightly prospected. [Laizure (1925)]
	Clear Creek Mine	Copper Mountain Sec 19, T5S, R6E	Manganese	Property not found in field. Manganese oxide ore interbedded with chert of Franciscan Complex. Workings included shallow inclines on outcrop and a tunnel. Production probably less than a few hundred tons. [Trask and others (1950, no. 6), Jenkins and others (1943), Bradley and others (1918)]
	Coast Manganese Mine	Lone Tree Creek Sec 11, T5S, R5E	Manganese	Property not found in field. Manganese oxide ore interbedded with massive and thin-bedded chert of Franciscan Complex. Workings include tunnel and shaft. Production reported to be 29 tons. [Trask and others (1950, no. 7), Jenkins and others (1943)]
	Crocker Prospect	Copper Mountain Sec 33, T5S, R6E	Manganese	Property reportedly undeveloped. Rocks of Section 33 are mapped as Franciscan Complex. [Trask and others (1950, no. 8), Jenkins and others (1943)]
	Grayson Prospect	Mt. Boardman SW4(?), Sec 21, T6S, R5E	Manganese	Descriptions in literature suggest this location. Reported occurrences of chert and manganese associated with old workings in cinnabar-bearing rock here. Rocks in this area are mapped as Franciscan Complex. [Trask and others (1950, no. 10), Watts (1892)]

MINES AND PROSPECTS--SOUTHWEST (PLATE 8A)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
	Grummett No. 2 Prospect	Solyo SE4, Sec 6, T5S, R6E	Manganese	Conflicting locations in literature and property reports. Information from site visits suggest that this property may be about 150 feet north of the Grummett-Knox Mine (property number 9). Workings consist of open cuts at opposite ends of a 360-foot long, northeast-trending zone of manganese oxide. Ore is associated with massive chert of Franciscan Complex. Probably little production, if any. [Trask and others (1950, no. 12), Jenkins and others (1943)]
	Hamilton Mine	Mt. Boardman Sec 27(?), T5S, R5E	Manganese	Property not found in field (reportedly about 1 mile southwest of Section 23 Mine). Rocks of Section 27 are mapped as Franciscan Complex. Production probably at least 500 tons of ore. [Trask and others (1950, no. 13), Jenkins and others (1943)]
	Jake Smith Prospect	Mt. Boardman Sec 22(?), T5S, R5E	Manganese	Property not found in field. Rocks in this section are mapped as Franciscan Complex. Reportedly 17 tons of ore shipped. [Trask and others (1950, no. 15), Jenkins and others (1943)]
	Thompson Brothers Prospect	Copper Mountain Sec 25, T5S, R5E	Manganese	Property not found in field. Rocks in Section 25 are mapped as Franciscan Complex. Reportedly produced 47 tons of ore. [Trask and others (1950, no. 27), Jenkins and others (1943)]

MINES AND PROSPECTS--CENTRAL (PLATE 8B)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
105	Dry Creek Pit/A. Teichert & Son, Inc.	Riverbank Sec 24, T3S, R9E	Base aggregate	In the early 1970s A. Teichert & Son, Inc. excavated an elevated terrace on the south side of Dry Creek. The material mined was primarily arkosic sands with lesser amounts of pea gravel.
101	Hatch Road Pit/Standard Materials Co.	Brush Lake Secs 1, 11, T4S, R8E	Base aggregate	Standard Materials Company excavated primarily sand and lesser amounts of gravel from Holocene terraces immediately to the south of the Tuolumne River in the 1970s. The material is arkosic and the sand is chiefly subangular to subrounded fine- to medium-grained quartz. The site is located north of Hatch Road, where Hatch Road intersects Vivian Road. The aggregate was used in road construction.
103	Hatch Road Pit/Putnam Sand and Gravel Co.	Brush Lake Sec 5, T4S, R9E	Base aggregate	Putnam Sand and Gravel Company excavated primarily sand and lesser amounts of pea gravel from an elevated Holocene terrace immediately to the north of the Tuolumne River during the early 1940s. The material is arkosic and the sand is chiefly angular to subrounded fine- to medium-grained quartz. The site is located at the south end of Sutter Avenue. The mined aggregate was used in road construction.
104	Greystone Block Company Pit/Greystone Block Company, Inc.	Riverbank Sec 32, T3S, R9E	Concrete aggregate	During the late 1950s and early 1960s Greystone Block Company, Inc. excavated sand and gravel from the active Tuolumne River near its intersection with Highway 99. The aggregate was screened and used in the manufacture of concrete block.
100	Ripon Pit/Modesto Sand and Gravel Co.	Salida Sec 29, T2S, R8E	Concrete aggregate	Modesto Sand and Gravel Co. began mining this 6-acre site for Holocene and Pleistocene fluvial sand during the late 1940s. Mining operations had ceased by 1966. The fine-grained quartzose sand was processed and marketed primarily for plaster sand. Sand thickness was about 25 feet. In 1989 Modesto Sand and Gravel Co. began recycling used concrete and asphalt trucked to this site. The recycled aggregate is processed for Class II road base.
102	Bonzi Pit/Rudy Bonzi	Brush Lake Sec 7, T4S, R9E	Fill aggregate	Rudy Bonzi has been mining fill sand and gravel from this site since 1977. The 52-acre site is located northwest of the intersection of Carpenter Road and Whitmore Avenue, and immediately north of Turlock Irrigation District Lateral No. 1 Canal. The bulk of the excavated material is fine- to medium grained 7-to 8-foot thick sand lenses with occasional 2- to 4-foot lenses of sandy pea gravel.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
180	Bearden Pit/M.J. Ruddy & Son, Inc.	Waterford and Paulsell Sec 27, T3S, R11E	Base aggregate	M.J. Ruddy mined sand and gravel at this 24-acre site from 1966 to the mid 1970s. Mining depths ranged from 15-20 feet. The mined material was from an elevated terrace of the Modesto Formation.
209	Borrow Pit/Caltrans	La Grange Secs 29, 30, 31, T3S, R14E	Base aggregate	This 112-acre site and surrounding region were extensively dredged for gold at various times from 1907 to 1952. During the 1960s and early 1970s massive tonnages of dredge tailings from this area were excavated by giant belly scrapers and used in the construction of the Don Pedro Dam a few miles to the east. From 1985 until about 1988 Caltrans excavated additional dredged tailings from this site for use in road construction. The tailings are an unsorted mixture of sand, gravel, cobbles, and boulders of the Pleistocene Riverbank Formation (and probably Turlock Lake Formation (?)).
129	Edwards Pit/Joel and Kathy Edwards	Knights Ferry Sec 36, T1S, R11E	Base aggregate	This site was dredged for gold in early 1940s. The dredged material consisted of Modesto Formation sand and gravel on elevated terraces to the north of the Stanislaus River. Thicknesses of dredge tailings ranged from 10-20 feet. Aggregate mining operations at this 5-acre site were conducted during 1978-1979.
135	Frymire Road Pit/Western Sand and Gravel Co.	Knights Ferry Sec 31, T1S, R12E	Base aggregate	Western Sand and Gravel Co. mined dredged tailings from this 8-acre site during the late 1970s; operations had ceased by 1980. The mined site is north of the Stanislaus River and due north of Lovers Leap. The elevated alluvial terrace material ranges in age from Holocene to Pleistocene Modesto Formation. Mining excavation depths ranged from 8-10 feet.
117	Gambini and Mondo Pits/Flintkote Co.	Escalon Secs 5, 8, T2S, R10E	Base aggregate	During the early and mid 1970s, Flintkote Co. mined elevated Stanislaus River terrace fluvial material from two adjacent pits at this 101-acre site. Pit names were taken from the names of the property owners. This deposit originally contained 7 to 8 feet of soil overburden underlain by up to 10 feet of predominately fine- and medium-grained sand, that in turn, was underlain by up to 8 feet of coarse sand and gravel. This deposit was composed of Modesto Formation alluvium and was a late Pleistocene elevated terrace of the Stanislaus River. The aggregate was processed at the site with a portable classifier and used as road base.
142	Griesner Pit/Elmer G. Wendt	Knights Ferry Sec 32, T1S, R12E	Base aggregate	This 30-acre site was dredged for gold during the 1930s. In 1968 Elmer Wendt began mining the dredge tailings for use as aggregate. The tailings are a mixture of Holocene alluvium and Modesto Formation, consisting of sands, gravels, cobbles, and boulders. Aggregate mining operations ceased in the mid 1970s.

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
200	La Grange Pit/Stanislaus Co. Dept. of Public Works	La Grange Sec 19, T3S, R14E	Base aggregate	Much of this 53-acre site was dredged for gold in the early 1900s. Since 1980 Stanislaus County has used dredge tailings from this site as aggregate for use as road base materials. An average tailings thickness of about 19 feet will eventually be excavated from this site before it is reclaimed; however, a remaining 3-15 foot thickness of dredged tailings will be left. The tailings are primarily a mixture of Holocene alluvium and Modesto Formation, consisting of sand, gravel, cobbles, and boulders. These tailings may also contain some older Riverbank Formation material that has been dredged from depth.
187	La Grange Pit/M.J. Ruddy & Son, Inc.	Cooperstown Secs 25, 35, 36, T3S, R12E; Secs 30, 31, T3S, R13E	Base aggregate	Nearly all of this site was dredged for gold in the late 1930s and early 1940s. This 945-acre site has been mined for aggregate since 1969. Prior to the current excavations by M.J. Ruddy & Son, Inc., aggregate mining operations at this site were conducted by the Flintkote Co. Average remaining thickness of dredge tailings ranges from 20-25 feet; however, maximum aggregate thickness may be as much as 40 feet. In places at this site, basement rock is at depths of 8-10 feet. The tailings are a mixture of Holocene alluvium and Modesto Formation, consisting of sand, gravel, cobbles, and boulders.
199	La Grange Pit/Standard Materials Co.	La Grange Secs 18, 19, T3S, R14E	Base aggregate	Since the early 1900s this site has been extensively dredged for gold. In the 1960s and early 1970s massive tonnages of dredged tailings were excavated from this site for use in the construction of Don Pedro Dam. Aggregate excavations ceased in 1972. The tailings are a mixture of Holocene alluvium and Modesto Formation, consisting of sand, gravel, cobbles, and boulders.
192	La Grange Pit/Flintkote Co.	Cooperstown Sec 35, T3S, R13E	Base aggregate	This site was dredged for gold during the 1920s. Dredge tailings were excavated from this site in the early 1960s for use in the Don Pedro Dam. The Flintkote Co. mined aggregate at this site from 1969 to about 1974. The excavated aggregate was then processed through a portable washing and sizing plant at this site. Depths of tailings averaged about 16 feet. The tailings are a mixture of Holocene alluvium and Modesto Formation, consisting of sand, gravel, cobbles, and boulders.
125	Orange Blossom Road Pit/Munn & Perkins, Inc.	Knights Ferry Secs 25, 36, T1S, R11E	Base aggregate	This site was dredged for gold during the early 1940s. In 1977 Munn & Perkins, Inc., began excavating the dredge tailings from this 70-acre site for use as aggregate. Thickness of dredged tailings averaged about 25 feet. Tailings consisted of sand and gravel from Holocene alluvium and the Modesto Formation, deposited as river terraces. The aggregate was trucked to the Munn & Perkins plant south of Escalon for processing and used in road base. The southern portion of this site has been reclaimed as part of the U.S. Army Corps of Engineers Horseshoe Bar Recreational Area.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
123	Orange Blossom Road Pit/Placer Properties Co.	Oakdale Sec 4, T2S, R11E	Base aggregate	Placer Properties Co. mined Holocene aggregate from this site on the north side of the Stanislaus River from 1939-1943. Subordinate amounts of gold were also recovered. Mining depths ranged from 12-15 feet. The U.S. Army Corps of Engineers has reclaimed a portion of this site as part of the Corps Orange Blossom Recreational Area. [Rapp and others (1977)]
141	Ritts Pit/Frank C. Alegre Co.	Knights Ferry Sec 32, T1S, R12E	Base aggregate	Alegre began mining this 10-acre site in 1975 and finished by the end of 1976. Average depths of aggregate ranged from 8-10 feet. This site contained predominately sand and pebble-sized clasts of the Modesto Formation. This deposit formed as an elevated terrace of the ancestral Stanislaus River probably during a period of inter-glacial outwash.
116	Riverbank Pit/Adams Sand and Gravel Co.	Riverbank Sec 19, T2S, R10E	Base aggregate	Adams Sand and Gravel Co. mined aggregate in the active channel and on the east bank of the Stanislaus River at this site during the 1950s and early 1960s. The excavated area was about 24 acres and has been reclaimed. Mining operations excavated aggregate from the active channel and from an adjacent Holocene elevated terrace to a depth of at least 10 feet.
130	Rodden Road Pit/Munn & Perkins, Inc.	Knights Ferry Secs 2, 3, T2S, R11E	Base aggregate	This 81-acre site was dredged for gold in the 1930s and early 1940s. In the mid 1970s Munn & Perkins, Inc., mined the dredge tailings at this site for use as aggregate. The aggregate mined at this site was a mixture of Holocene and older Modesto Formation and was processed primarily for use as road base materials. The mined aggregate thicknesses generally ranged from 20-30 feet.
109	Shirley Creek Site/Brichetto Ranch	Bachelor Valley Secs 19, 30, T1N, R11E	Base aggregate	Unconsolidated Holocene alluvium within the active Shirley Creek channel has been excavated for use as road aggregate at this site intermittently since the early 1900s. The operator has recently applied for a permit to mine road base materials within the Shirley Creek channel during periods when the channel is dry. Sand and gravel from this site has been used for many years by the Stanislaus County Department of Public Works in the construction of nearby Dunton Road and other local roads.
179	Waterford Pit/C. Skove & J. Wychopin Sand and Gravel Co.	Waterford Sec 33, T3S, R11E	Base aggregate	Skove and Wychopin mined sand and gravel from terraces on the north side of the Tuolumne River and from the active channel itself at this site during the late 1940s. [Charles (1947)]

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
172	Aldrich Road Pit/Flintkote Co.	Denair Secs 1, 2, T4S, R10E	Concrete aggregate	Harold J. Schmidt began mining sand and gravel at this site in 1955. From 1947 to 1961 Standard Materials Co. mined alluvial aggregate from the eastern portion of this site. In 1971 the Flintkote Co. was permitted to mine 80 acres at this site. The mined Holocene sand and gravel thicknesses ranged from 25-45 feet; however, aggregate thicknesses occasionally were much greater in some areas. Bucket-line dredging operations excavated sand and gravel to depths of 70 feet beneath the water line within the active Tuolumne River channel. The mined material from this site was processed for use in concrete and asphalt. Maximum sized aggregate was about 4 inches in diameter.
127	Ardis Pit North/George Reed, Inc.	Knights Ferry Secs 35, 36, T1S, R11E; Sec 2, T2S, R11E	Concrete aggregate	George Reed, Inc. has continuously mined this 45-acre site since 1985. Aggregate thicknesses generally range from 20-60 feet and average about 35 feet. Gold is also recovered. This deposit is primarily composed of sand and contains lesser amounts of subrounded to rounded gravel- and cobble-sized material. The predominant rock types include granitic rocks, quartzite, greenstone, basic volcanic rocks, and white vein quartz.
126	Ardis Pit South/George Reed, Inc.	Knights Ferry Secs 1, 2, T2S, R11E	Concrete aggregate	George Reed, Inc. mined sand and gravel at this 70-acre site from 1985 to 1992. Much of this site had been dredged for gold in the 1920s and 1930s. Maximum thickness of aggregate reached about 65 feet, however, the average aggregate thickness was about 15-20 feet. The mined material was a mixture of Holocene and Modesto Formation and was used for asphalt and road base materials.
189	Cree Ranch Pit/Western Stone Products, Inc.	Cooperstown Secs 31, 32, T3S, R13E	Concrete aggregate	This 178-acre site was dredged for gold in the late 1930s and early 1940s. It has been mined for aggregate since the 1960s. Prior to current excavations by Western Stone Products, Inc., this site was mined for aggregate by the Flintkote Co. Dredge tailings cover much of this site and are a mixture of Holocene and Modesto Formation sand, gravel, cobbles, and boulders. Aggregate thicknesses range from 25-40 feet. Bedrock occasionally occurs at depths of less than 20 feet.
118	Dixon Pit/Kauffman Gravel Co.	Oakdale Sec 9, T2S, R10E	Concrete aggregate	Kauffman Gravel Co. is reported to have mined in-channel and adjacent Holocene fluvial material at this site for base materials during the mid and late 1910s. This site was formerly mined by Mrs. Dixon of Oakdale. The sand and gravel was used for road construction and for concrete. [Lowell (1915), Boalich (1921)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
108	Dunton Road Site/Sam Langford & Thomas Ripley	Bachelor Valley Sec 24, T1N, R10E	Concrete aggregate	The operators are currently permitted to mine unconsolidated Holocene alluvial sand and gravel within Shirley and Hoods creek channels. Aggregate clasts are rounded and reach a maximum size of about 7 inches in diameter. Cobbles are chiefly composed of andesite, quartz and metamorphic basement material. Shirley and Hoods creeks are seasonal and commonly are dry during the late summer months. Sand and gravel have been extracted from Hoods and Shirley creeks since the early 1900s. Early-day mining operations consisted of hand shoveling the sand and gravel, then transporting it by mule-drawn wagon; most of the aggregate was used in constructing local roads. Current mining operations propose to transport the aggregate by truck to George Reed's Munn & Perkins Escalon plant to the northwest where it will be processed for use as asphaltic aggregate.
139	Frymire Road Pit/Oakdale Concrete and Pipe Co.	Knights Ferry Sec 29, T1S, R12E	Concrete aggregate	This 100-acre site was dredged for gold during the 1930s and early 1940s. In 1971 the Oakdale Concrete and Pipe Co. began mining the tailings at this site for aggregate for use in concrete and related products. Undredged aggregate from an in-channel gravel bar was also mined. These tailings are a mixture of Holocene and Modesto Formation sand, gravel, cobbles and boulders. The mined aggregate was trucked across the Stanislaus River and processed at Karl Ohe's plant at Lovers Leap. The site was abandoned by the late 1970s.
177	Hickman Pit/Western Stone Products, Inc.	Waterford Sec 32, T3S, R11E; Denair Sec 32, T3S, R11E; Sec 5, T4S, R11E	Concrete aggregate	This 90-acre site was originally mined for aggregate by Charles D. Warner & Son, Inc. in the 1960s and 1970s. Western Stone Products, Inc. began mining this site in 1988. Aggregate thicknesses generally range from 20-40 feet; however, in some areas near the Tuolumne River, aggregate thicknesses may reach nearly 100 feet.
132	Hodge Ranch Pit/George Reed, Inc.	Knights Ferry Sec 36, T1S, R11E	Concrete aggregate	George Reed, Inc. has continuously mined aggregate at this 16-acre site since 1988. This site is an elevated river terrace and is primarily composed of Holocene medium- to fine-grained sand with lesser amounts of pea gravel. The deposit thickness ranges from 25-35 feet. The aggregate is used for asphalt and road base materials.
128	Horseshoe Bar Pit/Flintkote Co.	Knights Ferry Secs 25, 35, 36, T1S, R11E; Sec 2, T2S, R11E	Concrete aggregate	Flintkote Co. mined several acres in this area on both sides of the Stanislaus River from the late 1960s through the early 1970s. Gold was also recovered. The mined aggregate was a mixture of unconsolidated Holocene and Modesto Formation sand, gravel, cobbles,and boulders. The mined material was used in a variety of construction projects including paving asphalt. The U.S. Army Corps of Engineers reclaimed this site, and this site is now part of the Corps Honolulu Bar and Horseshoe Bar recreational areas.

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
144	Knights Ferry Pit/Madonna Construction Co.	Knights Ferry Secs 29, 33, T1S, R12E	Concrete aggregate	Madonna Construction Co. mined this 134-acre site from 1975-1977. Deposit thickness ranged from 10 feet to 30 feet. The unconsolidated sand and gravel at this site was composed of Holocene and Modesto Formation. The material was processed for use as asphalt in the construction of Highway 120.
133	Lancaster Road Pit/Clayton Willms	Knights Ferry Secs 25, 31, 36, T1S, R11E; Secs 30, 31 T1S, R12E	Concrete aggregate	A portion of this 27-acre site was previously mined by the Flintkote Co. for aggregate. Karl Ohe mined selected portions of this site from 1985-1986. Most of the mined aggregate was taken from an elevated gravel bar next to the south bank of the Stanislaus River. The mined material was Holocene and Modesto Formation. Maximum aggregate thickness was about 20 feet. The sand and gravel was processed at Ohe's plant and used for concrete.
173	Landmark Pit/Western Stone Products, Inc.	Denair Sec 2, T4S, R10E	Concrete aggregate	In 1989 Western Stone Products, Inc. was permitted to mine 27 acres at this site. Thicknesses of elevated Holocene river terrace alluvium range from 30-40 feet. The aggregate is suitable for asphalt concrete and portland cement concrete products.
110	McHenry Avenue Pit/Munn & Perkins, Inc.	Escalon Sec 16, T2S, R9E	Concrete aggregate	Munn & Perkins, Inc. mined Pleistocene unconsolidated fluvial sand and gravel from an elevated terrace located immediately north of the Stanislaus River at this site during the 1950s and possibly in the early 1960s (?). The excavated area is about 800 feet in length, 200 feet in width and mined to a depth of from 10-15 feet. Cross-bedding is visible. Clasts are rounded to well rounded and contain a high percentage of granitic, volcanic, and metamorphic rock types. Maximum sized clasts are about 5 inches in diameter. The sand is arkosic and contains high percentages of quartz with lesser amounts of biotite and feldspars.
111	Munn & Perkins Pit/George Reed, Inc.	Escalon Secs 15, 22, T2S, R9E	Concrete aggregate	Dan B. Munn and Robert Perkins began mining aggregate at this 228-acre site in 1957, and mining has continued since then. George Reed, Inc. is the current operator. This deposit is composed of elevated Stanislaus River terraces of Modesto Formation and possibly younger Holocene sand and gravel (?). Large portions of this site had been dredged for gold in the 1930s; dredge tailings thicknesses were more than 50 feet thick in places. The tailings were excavated to a level such that about 12 feet remained, then reclaimed for agriculture. In undredged areas at this site, overburden varies from 2-3 feet. This deposit is about 65% arkosic sands, and 35% gravel and oversized material. Maximum sized clasts are about 8 inches in diameter. Aggregate from this site has been used in asphalt and concrete. The active asphaltic batch plant at this site is the principal supplier of asphaltic aggregate materials to the surrounding community.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
119	Oakdale Gravel Pit/Standard Rock Co.	Oakdale Sec 10, T2S, R10E	Concrete aggregate	During the early and mid 1910s mining operations in and adjacent to this site occurred within the active Stanislaus River channel and on adjacent Holocene terraces. Standard Rock Co. mined this site from 1947 to 1955 and use bucket-line dredges to excavate aggregate to a depth of 70 feet below the water table. The deposit consisted of 60% sand and 40% gravel and oversized material. Maximum sized cobbles were about 3 inches in diameter. The sand and gravel was used for concrete products and road aggregate. This site has since been reclaimed by the U.S. Army Corps of Engineers and is now the Corps' Oakdale Recreational Area.
121	Oakdale Pit/Dorsey Brothers Sand and Gravel Co.	Oakdale Secs 10, 11, T2S, R10E	Concrete aggregate	This site was mined for asphalt, road base, and concrete aggregate during the mid and late 1910s. Sand and gravel was excavated from the active channel and from adjacent Holocene river terraces. [Lowell (1915)]
136	Ohe Pit and Plant/Karl Ohe Sand and Gravel Co.	Knights Ferry Sec 31, T1S, R12E	Concrete aggregate	Karl Ohe began mining this 18-acre site in 1942 with a shovel and pick-up truck. Sand and gravel thicknesses at this site ranged from 12-18 feet. Gold was also recovered. This deposit formed as an elevated fluvial terrace of Modesto Formation sand and gravel during the upper Pleistocene. Holocene and late Pleistocene alluvium mined from the nearby Willms Pit a few hundred yards to the southeast is currently processed at the aggregate plant at this site. The sand and gravel is used for concrete.
113	Putnam Pit/Putnam Sand and Gravel Co.	Riverbank & Escalon Secs 23, 24, T2S, R9E	Concrete aggregate	This 10-acre site was mined for aggregate from 1924 to the early 1940s. There was little or no overburden. Aggregate thickness ranged from 20-30 feet and averaged about 25 feet. This site contained primarily sand with lesser amounts of gravel of small grain size. Some of the aggregate at this site was processed for use as plaster sand. This site formed as a late Pleistocene Modesto Formation elevated terrace of the Stanislaus River. [Clark (1955)]
112	Riverbank Pit/M.J. Ruddy Co.	Escalon Secs 23, 24, T2S, R9E	Concrete aggregate	This 19-acre site immediately to the west of Santa Fe Road was mined for aggregate by various operators from 1917 to 1947. In the late 1930s until 1944 this site was mined by the Santa Fe Sand and Gravel Company; processed quartzose sand from this site was used as railroad sand for braking. The last operator to mine this site was M.J. Ruddy Company (1944 to 1947). This deposit ranged in thickness from 20-25 feet. The primary products produced from this site were sand and 3/4 inch-minus gravel. This deposit is composed of Modesto Formation alluvium and formed as a late Pleistocene elevated terrace of the Stanislaus River. In addition to railroad sand, aggregate from this site was also used in asphalt and road base. [Clark (1955)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
114	Riverbank Pit/George Reed, Inc.	Riverbank Sec 24, T2S, R9E	Concrete aggregate	George Reed, Inc. is currently mining elevated terrace alluvium at this site. Pit depth ranges from 15-20 feet. The upper 7-12 feet of aggregate is late Pleistocene Modesto Formation. The lower unconsolidated 12-20 feet is older and is possibly Pleistocene Riverbank Formation or older Pliocene(?) sediments. Alluvial cross-bedding is prominent. Maximum sized clasts are about 8 inches in diameter. Aggregate from this site is used primarily in asphaltic products. The aggregate is trucked to the George Reed, Inc. processing plant south of Escalon.
186	Roberts Ferry Pit/7-11 Materials, Inc.	Cooperstown Secs 25, 26, T3S, R12E	Concrete aggregate	Much of this 26-acre site was dredged for gold by Yuba Consolidated Gold Fields in the 1930s and early 1940s. This site has been mined for aggregate since 1992. Depth of aggregate mining at this site ranges from 15-20 feet. The deposit consisted of a mixture of Holocene and Modesto Formation sand, gravel, cobbles, and boulders. The aggregate is used in concrete and related products.
203	Sarah Reeves Pit/ George Reed, Inc.	La Grange Secs 17, 18, T3S, R14E	Concrete aggregate	This 50-acre site was dredged for gold in the early 1900s. Since 1980 a portion of these dredge tailings have been excavated and stockpiled at the eastern portion of this site to allow for excavations of an underlying, coarse-grained, cross-bedded, unconsolidated arkosic sand (about 90%) and pea gravel (about 10%) unit that ranges in thickness from 15-25 feet. The aggregate is used in asphalt and in road base.
171	Schmidt Pit/Western Stone Products, Inc.	Denair Secs 2, 3, T4S, R10E	Concrete aggregate	The Flintkote Co. mined a portion of this 103-acre site in the 1970s. In 1989 Western Stone Products, Inc., began mining the remaining southeastern portion of this site. The Holocene material is excavated then trucked to the Western Stone Products, Inc., Hughson plant a few miles to the east. The sand and gravel is primarily used for asphalt, concrete, and road base aggregate.
170	Schmidt Pit/Flintkote Co.	Denair Secs 3, 4, T4S, R10E	Concrete aggregate	Portions of this 80-acre site were formerly mined by Standard Materials Co. from the mid 1960s to the late 1960s. In 1971 Flintkote Co. began mining operations at this site. Average thickness of the mined Holocene sand and gravel ranged from 20-25 feet; however, some areas were mined to depths of about 50 feet. Most of this former mine site has been reclaimed for farming. The material from this site was principally used for asphaltic and road base aggregate.
122	Stearns Road Pit/Atlas Rock Co.	Oakdale Sec 6, T2S, R11E	Concrete aggregate	During the 1920s Atlas-Olympia Rock Co. (later changed to Atlas Rock Co.) mined substantial tonnages of aggregate from the active Stanislaus River channel and from adjacent terraces for use as concrete and asphaltic materials. The mined sand and gravel was Holocene alluvium and Modesto Formation. Aggregate from this 167-acre site was processed and shipped via railroad cars. Much of it was used in the construction of the O'Shaunessy Dam at the Hetch Hetchy Reservoir. [Laizure (1925)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
176	Tuolumne River Pit/Santa Fe Rock and Sand Co.	Denair Secs 5, 6, T4s, R11E	Concrete aggregate	In 1947 Santa Fe Rock and Sand Co. began mining Holocene alluvial terrace sand and gravel at this site. The material was mined to depths of 7-12 feet. Sand and gravel were processed at the site for use in concrete and asphalt.
174	Tuolumne River Pit/American Sand and Gravel Co.	Denair Secs 35, 36, T3S, R10E; Sec 1, T4s, R10E	Concrete aggregate	American Sand and Gravel Co. mined this site in the late 1950s and early 1960s. Aggregate was mined from the active stream channel and from adjacent Holocene river terraces to the north. The mined material was used for plaster sand, concrete, and asphalt. Nearly 70% of the aggregate from the elevated terraces was sand-sized. Maximum sized aggregate was 4 inches in diameter.
183	Warner Sand Pit/Hollis & Joyce Warner	Paulsell Sec 32, T3S, R12E	Concrete aggregate	In 1980 Hollis and Joyce Warner began excavating this 15-acre site. This site was composed of medium- to fine-grained Modesto Formation sand formed by eolian processes during the Holocene. The sand formed a low rounded hill against the southern-most portion of an elevated Pleistocene river terrace. Sand thickness ranged from 11-25 feet. The material was processed and used in concrete and asphalt.
175	Warner Pit & Hughson Plant/Western Stone Products, Inc.	Waterford and Denair Sec 32, T3S, R11E; Sec 5, T4S, R11E	Concrete aggregate	From 1946 to the late 1970s this 94-acre site was mined by Charles D. Warner & Son, Inc. In-channel mining operations reached hard bedrock at 40 feet beneath the water line near the Tuolumne River channel. Maximum thicknesses of Holocene age sand and gravel on elevated river terraces were over 60 feet. Western Stone Products, Inc. is currently mining the remaining deposits at this site. The aggregate is used for asphalt and concrete products.
178	Waterford Pit/Putnam Sand and Gravel Co.	Waterford Sec 33, T3S, R11E	Concrete aggregate	Putnam Sand and Gravel Co. began mining the active Tuolumne River channel at this site during 1957. It later mined elevated Holocene river terraces just south of the channel. In-channel mining thicknesses reached 20 feet; off-channel thicknesses reached 30 feet. The aggregate was processed for use as concrete and road construction materials. Maximum sized aggregate was 4-5 inches in diameter. This site was abandoned in the late 1960s.
182	Waterford Pit/M.J. Ruddy & Son, Inc.	Paulsell Secs 28, 29, 32, 33, 34, T3S, R12E	Concrete aggregate	Mining operations at this 492-acre site have been on-going since 1965. Much of this site has been depleted of aggregate. The Roen processing plant is located on the north side of the Tuolumne River. Mined aggregate from the south side of the river is transported via conveyor belt to the plant. M.J. Ruddy & Son, Inc. are currently mining 175 acres of this site. Overburden ranges in thickness from 2-10 feet. Sand and gravel thicknesses range from 20-30 feet. This deposit formed as elevated Holocene alluvial terraces on banks adjacent to the Tuolumne River. The aggregate is used in concrete and asphalt.
181	Waterford Pit/George Reed, Inc.	Paulsell Secs 25, 36, T3S, R11E	Concrete aggregate	George Reed, Inc. mined this site from the 1950s to the 1980s. The aggregate was mined to depths of 30 feet. It was used in portland cement concrete and asphaltic concrete.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
184	Waterford Pit/7-11 Materials, Inc.	Paulsell Secs 27, 34, 35, T3S, R12E	Concrete aggregate	Aggregate mining operations at this 141-acre site have been on-going since 1962. Overburden ranges in thickness from 0-8 feet. Deposit thickness ranges from 15-35 feet. 7-11 Materials, Inc. is currently mining the Holocene and elevated terrace Modesto Formation sand and gravel at this site. The aggregate is used in concrete and related products.
120	Wheeler Pit/W.F. Wheeler Gravel Co.	Oakdale Secs 10, 11, T2S, R10E	Concrete aggregate	During the 1910s W.F. Wheeler Gravel Co. extracted alluvium from the active river channel and from adjacent Holocene river terraces. The sand and gravel from this site was primarily used for road construction and concrete.
137	Wildcat Creek Pit/Karl Ohe Sand and Gravel Co.	Knights Ferry Sec 31, T1S, R12E	Concrete aggregate	This 63-acre site was mined in small parcels from 1978 to 1989. As each area was mined and reclaimed, a few acres from a nearby site was permitted for mining. Thickness of the sand and gravel generally ranged from 10-25 feet. Overburden varied from a few inches to 3 feet. The deposit was an elevated fluvial terrace of the Stanislaus River and contained Modesto Formation material. The mined material was trucked a few hundred yards north across Highway 120 to the Ohe plant and processed primarily for use in concrete.
134	Willms Upper Pit/Clayton Willms	Knights Ferry Secs 25, 36, T1S, R12E	Concrete aggregate	The elevated alluvial channel bar deposits at this 68-acre site were dredged for gold in the 1930s and early 1940s. The dredged tailings were mined for aggregate from 1978-1981. Sand and gravel were a mixture of Holocene alluvium and Modesto Formation. The aggregate was used primarily in portland cement concrete.
140	Willms Ranch Pit/Karl Ohe Sand and Gravel Co.	Knights Ferry Sec 32, T1S, R12E	Concrete aggregate	Mining in this 8-acre site has been on-going since 1992. The aggregate is Holocene sand, gravel and cobbles. Overburden varies from 1-3 feet. The deposit thickness varies from 15-25 feet. The material is primarily composed of cross-bedded arkosic sands interbedded with lenses of 2- to 9-foot-thick gravel and cobble strata. The gravel and coarser-grained clasts are well-rounded. Maximum sized boulders are nearly 3 feet in diameter.
160	Cooperstown Pit	Cooperstown SE4, Sec 21, T2S, R13E	Clay	Oval-shaped open pit cut into intensely leached metamorphic basement. Basement shows schistose structure preserved in places. Rock is altered to white and ferruginous clay. White clay is kaolinitic with high silica content. Pit is about 100 feet by 60 feet maximum, with maximum depth of about 25 feet. Total disturbed area is about 100 feet by 175 feet.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
161	Cooperstown Pit	Cooperstown SE4, Sec 21, T2S, R13E	Clay	Open cut in intensely leached metamorphic basement. Basement shows schistose structure in places. Rock is altered to clay that ranges from white to light orange. A few percent quartz grains and some small quartz veins present. Chemical analysis shows kaolinite and high-silica (higher than clays of Ione Formation). Outcrop area of altered material is about 200 feet by 200 feet. Small open cut follows strike of metamorphic foliation; dimensions are 125 feet by 30 feet, with maximum depth about 20 feet. Total disturbed area is about 300 feet by 350 feet. Some of the area outside the open cut may have been scalped.
162	Cooperstown Pit	Cooperstown SE4, Sec 21, T2S, R13E	Clay	Minor workings in intensely leached metamorphic basement. Basement shows schistose structure, which dips steeply to east. Workings are cut orthogonal to metamorphic foliation. Basement is altered to clay, which consists of kaolinite and silica; color ranges from cream to yellowish-orange. Foliation cut by many white quartz veins. Workings consist of a trench about 175 feet by 20-25 feet, with a maximum height of about 8 feet. Dimensions of total disturbed area are about 50 feet by 350 feet, which include the trench.
165	Curtoni Pit	Cooperstown SE4, Sec 27, T2S, R13E	Clay (ball)	Large open pit in claystone of Ione Formation. Maximum dimensions are about 200 feet by 400 feet with maximum depth of a few tens of feet. Exposed in pit floor is light-gray weathering kaolinitic clay, not completely mined out. Sides and bottom of pit show slumps in places.
166	Curtoni Pit	Cooperstown SE4, Sec 27, T2S, R13E	Clay (ball)	Small pit cut into shallow swale underlain by Ione Formation. Pit is about 50 feet by 75 feet, while total disturbed area is about 150 feet by 250 feet. Pit is relatively shallow; material in stockpiles appears to be ferruginous sandstone and conglomerate. Excavation may not have been deep enough to reach claystone horizon mined west of this area.
167	Curtoni Pit	Cooperstown SE4, Sec 27, T2S, R13E	Clay (ball)	Appears to be main original workings. Site of stockpiles of overburden and clay. Excavation into sandstone and claystone of Ione Formation. One pit face exposes vertical section about 40 feet thick, with about 15 feet of weathered sandstone and conglomerate horizons overlying at least 25 feet of tan claystone, which weathers light-gray. Reserves have not been exhausted and probably continue to the northwest. Small pond occupies main pit area between stockpiles. Original dimensions of excavated area unknown. Mined mostly for use in sanitary ware.
168	Curtoni Pit	Cooperstown SE4, Sec 27, T2S, R13E	Clay (ball)	Small pit cut into gentle slope south of main pits. Area underlain by Ione Formation, with stratigraphy same as at main pits. Size of pit about 100 feet by 150 feet, with face height 20 feet maximum on south, tapering to zero on north. Claystone still exposed on pit floor.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
169	Curtoni Pit	Cooperstown SE4, Sec 27, T2S, R13E	Clay (ball)	Small pit probably excavated as exploratory trench. Cut into Ione Formation.
196	Kraftile Pit	La Grange SE4, Sec 7, T3S, R14E	Clay (ball)	Large open pit cut into Ione Formation. Operated by Kraftile Company from 1959 to middle 1980s as a source of ball clay for manufacture of floor and wall tiles. Stratigraphy consists of sandstone overlying gray to tan kaolinitic claystone, which varies in thickness because of irregular surface of deposition. Material mined was probably less than 50,000 tons. Reported measured reserves of site originally at about 250,000 tons. Total disturbed area is about 450 feet by 650 feet, elongate to the west. Stockpile on north side of area is about 150 feet by 650 feet, with maximum height of a few tens of feet; may be mostly ferruginous sandstone (overburden). South face of pit is about 25 feet high above a pond. Site is idle and now used for storage of heavy equipment. [Wild and Key (1963)]
151	Mine (name unknown)	Knights Ferry NE4, Sec 29, T1S, R12E	Clay (ball)	North-trending elongate open pit cut at least partly into Ione Formation. Bottom of pit occupied by pond. Heavily vegetated, which indicates property has not been worked in many years. On west side of pit, yellow ochre is exposed. On east side, laminated silty claystone is exposed. Commodity mined here is inferred to be clay. Upslope to the east of this pit is a more-recent excavated area, which exposes gray-weathering clay.
149	Winkler Pit	Knights Ferry NE4, Sec 29, T1S, R12E	Clay (ball)	Large open pit first worked at least as early as 1933. Probably first mine in county worked for ceramic-grade clay. Pit is cut into moderate slope underlain by Ione Formation. Excellent exposure of sandstone overlying kaolinitic claystone, which is light brown, weathering to gray. Section dips gently to west. Claystone horizon may be as thick as 25 feet. Claystone overlain by 6-inch thick hematitic iron cap, which is overlain by a hard limonitic zone and then softer ferruginous sandstone. Pit is about 50-100 feet by 250 feet in area. Small shafts are present in the surrounding slopes. [Charles (1947)]
155	49er Pit (Rodden Ranch)	Keystone NE4, Sec 17, T2S, R13E	Clay (ball)	Open pit in Ione Formation. Probably operated during 1960s, although material was still removed from a high-grade stockpile as late as about early 1992. Material consisted of chocolate brown, organic-rich kaolinitic clay. Overburden consisted of iron-stained clay that is still present in three stockpiles on edges of pit. One stockpile has a maximum height of about 20 feet. Pit dimensions are about 100 feet by 700 feet. A pond occupies most of the pit. Overburden stockpile might be source of material for low-grade uses.
107	Dredge Field	Valley Springs SW Secs 8, 9, T2N, R10E	Gold	Area of dredging in Quaternary gold-bearing alluvial deposits along South Gulch. Total area less than a few hundred acres. May have been operated by California Gold Dredging Company. [Valley Springs SW 7.5-minute quadrangle (1973)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
115	Dredge Field	Riverbank Sec 24, T2S, R9E	Gold	Area dredged, reportedly in 1930s, for gold-bearing alluvial deposits within Modesto Formation. Area disturbed is less than 200 acres. [Riverbank 7.5-minute quadrangle (1987)]
143	Dredge Field	Knights Ferry Secs 29, 32, T1S, R12E	Gold	Tailings area in workings cut into gold-bearing alluvial deposits of Modesto Formation and possibly Riverbank Formation. Some of workings appear to be from hydraulic methods. [Knights Ferry 7.5-minute quadrangle (1987)]
124	Dredge Field (Placer Properties)	Knight Ferry, Oakdale, Secs 3, 4, T2S, R11E	Gold	Dredged area along Stanislaus River reportedly active during early 1940s. Material worked consisted of Quaternary gold-bearing alluvial deposits. [Knights Ferry 7.5-minute quadrangle (1987); Averill (1946)]
131	Dredge Field (Placer Properties?)	Knights Ferry Secs 35, 36, T1S, R11E	Gold	Quadrangle shows tailings along Stanislaus River. Area worked includes Quaternary gold-bearing alluvial deposits. Placer Properties Company reportedly worked about 9 miles east of Oakdale, which may have been this site. [Knights Ferry 7.5-minute quadrangle (1987); Averill (1946)]
208	Dredge Field (Tuolumne Gold Dredging)	La Grange Sec 36, T3S, R13E; Secs 29, 30, 31, 32, T3S, R14E	Gold	This area was worked by the Tuolumne Dredge, probably the second most productive dredge in the county. Operations were from 1938-1943 and 1945, perhaps into the late 1940s or early 1950s. workings cover a few hundred acres in Modesto Formation and older gold-bearing alluvial deposits. Reported to be difficult dredging because of consolidated character of deposits as well as drainage problems associated with working of older hydraulic areas. Remains of dredge are in an undeveloped county park, south of Dawson Lake. [Charles (1947), Anonymous (1946), Clark (1970)]
138	Dredge Field (Yankee Hill Gold Dredging)	Knights Ferry Secs 31, 32, T1S, R12E	Gold	Area of dredging on both sides of Stanislaus River. Material worked includes Quaternary gold-bearing alluvial deposits. Reportedly worked around 1920. [Boalich (1921), Laizure (1925)]
185	Dredge Field (Yuba Consolidated Gold Fields)	Paulsell Secs 33, 34, T3S, R12E	Gold	Area of Holocene gold-bearing alluvial deposits dredged beginning in 1941. Operation reportedly shut down in World War II. Not known if activity ever resumed. [Charles (1947)]
106	Dredge Field (California Gold Dredging)	Valley Springs SW Sec 6, T2N, R10E; Sec 31, T3N, R10E	Gold, silver	Extensive area dredged probably in 1930s and 1940s. Area consists of a few hundred acres within gold-bearing alluvial deposits of Laguna Formation. Site of aggregate mining at present in adjacent San Joaquin County. [Valley Springs SW 7.5-minute quadrangle (1973), Averill (1946)]

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
188 190 191 193 198	Dredge Field (La Grange Gold Dredging)	Cooperstown, La Grange Secs 25, 35, 36, T3S, R12E; Secs 24, 25, 30, 31, 32, 33, 34, 35, 36, T3S, R13E; Secs 17, 18, 19, 20, T3S, R14E	Gold, silver, platinum	Area of the most productive gold-mining operation in the county. Mined by a 62-bucket dredge, which began operation in 1907 and continued to 1942. Following World War II, it operated from 1945 to 1951. Has the distinction of the longest continuous operation of any dredge in California. Reported to have processed at least 70,000,000 cubic yards of material, about 16,000,000 of which were later used in construction of New Don Pedro Dam. Area worked included that from La Grange to about 9 miles downstream. Material worked consisted mainly of Holocene channel deposits and Modesto Formation, within and adjacent to the channel of the Tuolumne River. Gravels were reported to be worked to an average depth of 30-35 feet. Reported average yield during 1920s was about 12 cents per cubic yard. [Charles (1947), Laizure (1925, 1935), Lowell (1915), Aubury (1910)]
206	French Pit	La Grange SW4, Sec 20, T3S, R14E	Gold	Historical placer workings just southeast of La Grange. Area underlain by alluvium of Riverbank Formation, deposited on metamorphic basement. Probably worked by both manual and hydraulic methods. [La Grange 7.5-minute quadrangle (1987)]
207	Patricksville(?) Pit	La Grange SE4, Sec 30, T3S, R14E	Gold	Inferred location of Patricksville Diggins, which were reportedly active in the 1880s. Workings include a north-facing hydraulic mine in Cenozoic gold-bearing alluvial deposits. Subsequent to the hydraulic mining, these deposits were worked by tunneling. [Anonymous (1946)]
145	Placer Mine (name unknown)	Knights Ferry NW4, Sec 29, T1S, R12E	Gold	Tailings shown in area mapped as Mehrten Formation. Workings may be in small, unmapped remnant of a younger gold-bearing alluvial deposit. [Knights Ferry 7.5-minute quadrangle (1987)]
146	Placer Mine (name unknown)	Knights Ferry SE4, Sec 20, T1S, R12E	Gold	Tailings area from hydraulic mining of gold-bearing alluvial deposits of Laguna Formation. [Knights Ferry 7.5-minute quadrangle (1987)]
147	Placer Mine (name unknown)	Knights Ferry SE4, Sec 20, T1S, R12E	Gold	Small area of tailings associated with hydraulic mining of gold-bearing alluvial deposits, probably within the Laguna Formation. [Knights Ferry 7.5-minute quadrangle (1987)]
148	Placer Mine (name unknown)	Knights Ferry NE4, Sec 29, T1S, R12E	Gold	Extensive hydraulic area within gold-bearing alluvial deposits of the Laguna Formation. Deposits are well-consolidated and consist mainly of coarse sand, and pebble and cobble conglomerate. Heavily stained with hematite, which is characteristic of this unit in this area.
153	Placer Mine (name unknown)	Knights Ferry NW4, Sec 28, T1S, R12E	Gold	Extensive hydraulic area within gold-bearing alluvial deposits of the Laguna Formation. Deposits here are well-consolidated and consist mainly of coarse sand, abundantly stained with hematite.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
202	Placer Mine (name unknown)	La Grange SW4, Sec 17, T3S, R14E	Gold	Hydraulic pit in gold-bearing sandstone of Ione Formation. Pit dimensions about 150 feet by 300 feet; depth averages about 10-15 feet.
204	Placer Mine (name unknown)	La Grange SW4, Sec 17, T3S, R14E	Gold	Hydraulic pit cut into strata of Ione Formation.
205	Placer Mine (name unknown)	La Grange SE4, Sec 17, T3S, R14E	Gold	Placer workings about 250 feet in diameter. Cobble conglomerate with strong hematitic soil development. Units mined are Ione Formation and North Merced Gravel, which overlie Merced Falls Slate.
211	Placer Mine (name unknown)	Snelling SE4, Sec 1, T4S, R13E	Gold	Geologic map shows area of tailings in gully. [Marchand (1981)]
150	Mine (name unknown)	Knights Ferry NE4, Sec 29, T1S, R12E	Mineral Pigment (ochre)	Partially covered, south-trending adit. Yellow ochre is visible just inside portal. Material is soft, orange-yellow, and fairly clean. In nearby outcrop, hematitic iron-cap layers are adjacent to ochre. Could be one of properties described below but not shown on map because of ambiguous reported location.
156	Quarry (name unknown)	Cooperstown SW4, Sec 21, T2S, R13E	Stone (Dimension)	Small workings in variegated sandstone of Ione Formation. Disturbed area is about 50 feet by 100 feet. Cuts made by bulldozer.
157	Quarry (name unknown)	Cooperstown SW4, Sec 21, T2S, R13E	Stone (Dimension)	Small cuts in well-indurated, variegated sandstone of Ione Formation. Colors generally pink and light red. Each cut is a few tens of feet long.
158	Quarry (name unknown)	Cooperstown SW4, Sec 21, T2S, R13E	Stone (Dimension)	Quarry around circumference of hill top in well-indurated sandstone of Ione Formation. Limonite and hematite produce yellow and pinkish-red colors, respectively. Exposed thickness of sandstone in quarry is about 20-25 feet. Thickness of Ione Formation here is estimated to be 85-90 feet. A few conglomerate horizons are present, including one six-inch layer exposed around the entire circumference of the quarry road.
159	Quarry (name unknown)	Cooperstown SW4, Sec 21, T2S, R13E	Stone (Dimension)	Small open cut in well-indurated variegated sandstone of Ione Formation. Rock exhibits both yellow and red color from limonite and hematite. Small stockpile (about one cubic yard) of this material. Total disturbed area is about 50 feet by 150 feet.

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
163	Quarry (name unknown)	Cooperstown NW4, Sec 28, T2S, R13E	Stone (Dimension)	Extensive sidehill cuts in moderate- to well-indurated, variegated sandstone of Ione Formation. Material exhibits mainly red color, with minor yellow zones. Fractures into irregular blocks; there is no prominent foliation that produces a platy fracture. Workings are on two main levels around south and east sides of hill (quarry symbol on quadrangle map is mislocated too far to the west). Upper level extends for about 800 feet in length. Lower level is shorter, but is in harder rock in places (massive, very dense). Maximum heights of faces are about 10-15 feet. Width of disturbed area is a few hundred feet.
164	Quarry (name unknown)	Cooperstown NE4, Sec 28, T2S, R13E	Stone (Dimension)	North-facing open cut on side of hill. Material exposed is indurated, variegated sandstone of Ione Formation. Mostly red, with patches of gray; minor yellow zones. Colors somewhat mottled. Main cut is about 250 feet long, with faces about 3-5 feet high maximum. Total disturbed area is about 50 feet by 300 feet.
197	Quarry (name unknown)	La Grange NE4, Sec 18, T3S, R14E	Stone (Dimension)	Elongate open cut in variegated sandstone of Ione Formation. Material exhibits shades of pink, orange, red, and yellow, and is easily broken with hammer, which suggests large percentage of clay in rock. Horizon dips gently to west. Workings consist of west-facing open cut about 125 feet long, with height of face about 10 feet maximum. Large enough to have had some commercial production. Another minor cut just north of main cut. Total disturbed area about 75 feet by 150 feet.
201	Quarry (name unknown)	La Grange SW4, Sec 17, T3S, R14E	Stone (Dimension) Gold(?)	Large open cut into Ione Formation. May have originally been a placer gold operation, with later mining for stone and/or clay. North wall of pit has good exposure of section of Ione Formation about 40-50 feet thick, with sandstone overlying kaolinitic claystone. Claystone is very light gray and at least 12 feet thick. Pit is about 200 feet by 400-500 feet, with depths up to 50-75 feet in places.
152	Wright Ranch (?) Quarry	Knights Ferry SW4, Sec 21, T1S, R12E	Stone (Dimension)	Irregular quarry in well-cemented, ferruginous sandstone of Ione Formation. Characteristics match that of Wright Ranch Quarry described in literature. Workings are a few hundred feet long. [Aubury (1906)]
154	Prospect	Keystone NW4, Sec 17, T2S, R13E	Unknown Gold(?)	Very small open cut in metamorphosed volcanic rock that shows hydrothermal alteration. Part of a larger area that exhibits both silicic and sericitic alteration. Workings excavated probably for gold or base metals (copper, zinc).
194	Prospect	La Grange SE4, Sec 24, T3S, R13E	Unknown	Shown as prospect symbol, which plots in Valley Springs Formation. Site not visited. [La Grange 7.5-minute quadrangle (1987)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MO)	COMMOOITY	COMMENTS ANO REFERENCES
195	Prospect	La Grange NE4, Sec 12, T3S, R13E	Unknown Clay(?)	Small open cut and several bulldozer cuts into hill. Open cut exposes Ione Formation, which consists of strongly weathered cobble conglomerate; most clasts altered to clay, while matrix has some sand, but is largely white or light gray clay. Open cut is about 60 feet x 100 feet. Total disturbed area is about 150 x 300 feet. Exploration may have been for clay.
210	Prospect	Snelling SE4, Sec 1, T4S, R13E	Unknown Gold(?)	Symbol showing west-trending adit in hill. Tailings are in gully below, which suggests the underground workings were excavated in search of gold. [Snelling 7.5-minute quadrangle (1962)]
	Mueller Ranch Site/Granite Construction Co.	Valley Springs SW Sec 1, T2N, R9E; Sec 6, T2N, R10E	Concrete Aggregate	Granite Construction Co. is currently requesting a permit to mine sand and gravel at this 832-acre site. The northern third of this site was dredged for gold in the 1930s; however, the entire area is composed of the same lithology. The aggregate within this site contains a high percentage of clay and is part of an elevated terrace of the Calaveras River. The material is composed of Pliocene Laguna Formation alluvium. (See Plate 2C, Mine Site No. 1 for location.)
	Waterford Site/George Reed, Inc.	Paulsell Secs 30, 31, T3S, R12E; Secs 25, 36 T3S, R11E.	Concrete aggregate	George Reed, Inc. is currently permitted to mine this 305-acre area. A 42-acre parcel in the northwestern portion of this site was mined by George Reed, Inc. in the 1970s. Aggregate thickness generally ranges from 12-30 feet. The aggregate occurs in elevated terraces and is composed of the Modesto Formation alluvium. (See Plate 2C, Mine Site No. 13 for location.)
	Craycroft Pit	Riverbank T3S, R9E	Clay (common)	Common clay probably obtained from Modesto Formation for manufacture of brick for buildings. Pit reportedly was within city limits of Modesto, probably between 1907 and 1916. [Lowell (1915), Laizure (1925)]
	Cummings Ranch Prospect	Patterson Sec 20, 21, T5S, R7E	Clay (kaolinitic(?))	Reported location is "northeast" of Patterson, but township-range location puts it in Del Puerto Canyon. Reported analysis is 60 percent silica, 24 percent alumina, 3 percent iron, and a little magnesia. May be associated with Tesla Formation. [Lowell (1915), Laizure (1925)]
	Kelch Pit	Riverbank T3S, R9E	Clay (common)	Location of pit reportedly one mile east of Modesto along Waterford Road. Clay deposit had maximum thickness of 20 feet and was probably mined from Modesto Formation. Reportedly active in 1918-1919. [Laizure (1925)]
	Dredge Field (C and E Dredging)	Knights Ferry T1S, R12E	Gold	Dragline dredge reportedly operated on Littlejohn Creek, about 2 miles northwest of Knights Ferry in early 1940s. Material mined was probably Holocene channel deposits and Modesto Formation. [Averill (1946), Charles (1947)]
	Dredge Field (California Gold Dredging)	Farmington Sec 28(?), T2N, R10E	Gold, silver	Reported location plots along or near Duck Creek. This activity not substantiated in literature researched. [U.S. Bureau of Mines (unpublished data)]

MINES AND PROSPECTS--NORTHEAST (PLATE 8C)

MAP NO.	MINE NAME/OPERATOR	7.5' QUAD SEC/TN/RNG (MD)	COMMODITY	COMMENTS AND REFERENCES
	Dredge Field (C.F. Vanciel)	Knights Ferry T1S, R12E	Gold,silver	Operation was reportedly on "Anderson, Higginbotham, and Kaasa" property at least during 1941 and 1942. Location of this property not researched. [Averill (1946), Charles (1947)]
	Frymire Ranch Mine	Knights Ferry Sec 29, T1S, R12E	Gold	May be small workings near east end of Frymire Road. Reported placer workings, perhaps in older Quaternary gold-bearing alluvial deposits. [U.S. Bureau of Mines (unpublished data)]
	Many	Various along Stanislaus and Tuolumne Rivers	Gold	For many years, various producers of sand and gravel along both the Stanislaus and Tuolumne Rivers have recovered placer gold as a by-product of their operations. [Koschmann and Bergendahl (1968)]
	Bartlett Ranch Mine	Knights Ferry Sec 29, T1S, R12E	Mineral Pigment (ochre)	Tunnel reportedly at least 160 feet long cut into yellow ochre of Ione Formation. Reported to adjoin the Voyle Mine. [Boalich (1921), Charles (1947)]
	Pentland Mine	Knights Ferry Sec 29(?), T1S, R12E	Mineral Pigment (ochre)	Reported to be one-quarter mile southwest of Knights Ferry, although township-range data given contradict this location. Yellow ochre mined from Ione Formation. [Aubury (1906)]
	Shafer Mine	Knights Ferry Sec 29, T1S, R12E	Mineral Pigment (ochre)	Operation reportedly one-quarter mile from Voyle Mine. Yellow ochre mined from Ione Formation. Workings were underground. [Laizure (1925)]
	Voyle Mine	Knights Ferry NE4, Sec 29, T1S, R12E	Mineral Pigment (ochre)	The most important producer of yellow ochre in Stanislaus County. Photographs suggest location on a south-facing slope, possibly just west of Winkler Pit (clay). Workings were underground in a nearly flat bed from 4-8 feet thick that is part of the Ione Formation. Reportedly averaged 150 tons annual production for several years. Material probably used mostly in paint. [Aubury (1906), Lowell (1915), Laizure (1925)]
	Wideman Ranch Mine	Knights Ferry Sec 29, T1S, R12E	Mineral Pigment (ochre)	Reportedly on south side of Stanislaus River, directly opposite Knights Ferry. Drifts followed horizon of yellow ochre about 4-6 feet thick in Ione Formation. [Laizure (1925)]

APPENDIX B

Geochemical Data

EXPLANATION

Listed in this appendix are chemical analyses and brightness measurements for rock samples collected throughout Stanislaus County during this study. Locations of all samples, with the exception of STC-31 and STS-52b, are shown by circled numbers on Plate 8A (STC samples) and Plate 8C (STS samples). STC-31 was collected at Mine Locality Number 89 on Plate 8A. STS-52b was collected at Mine Locality Number 149 on Plate 8C.

Regarding the letters on X-ray diffraction peaks in Figures B-3 through B-12, the following scheme applies: Q = quartz, K = kaolinite, S = smectite, I = illite.

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TABLE B-2. Whole-rock analysis.....B4

TABLE B-3. 16-element assay.....B5

TABLE B-4. Metal assay.....B5

TABLE B-5. Fire assay.....B5

TABLE B-6. Weight percentages of minerals.....B6

TABLE B-7. Brightness measurements.....B7

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FIGURES B-1 to B-12. X-ray diffraction patterns.....B8

SAMPLES ANALYZED

STC-002b	Alpine Peridotite Member, harzburgite unit (CRO)
STC-005	Alpine Peridotite Member, dunite-wehrlite unit (CRO)
STC-011	Alpine peridotite Member, dunite-wehrlite unit, chromite ore (CRO)
STC-014a	Kreyenhagen Shale, diatomite
STC-018b	Alpine peridotite Member, dunite-wehrlite unit, chromite ore (CRO)
STC-020	Alpine peridotite Member, dunite-wehrlite unit, chromite ore (CRO)
STC-023	Alpine Peridotite Member, harzburgite unit, magnesite (CRO)
STC-031	Kreyenhagen Shale, diatomite
STC-035	Tesla Formation, "C" sandstone
STC-037	Tesla Formation, "B" sandstone
STC-040c	Kreyenhagen Shale, diatomite
STC-045a	Kreyenhagen Shale, diatomite
STC-056	Volcanic Member, keratophyre (CRO)
STC-059	Quartz vein in Plutonic Member (CRO)
STC-064a	Poverty Flat Sandstone, sandstone
STC-069b	Valley Springs Formation, claystone
STC-071	Tertiary volcanic dike
STC-074	Franciscan Complex, hydrothermally altered graywacke
STC-075a	Franciscan Complex, hydrothermally altered chert
STC-077	Franciscan Complex, hydrothermally altered graywacke
STC-079	Franciscan Complex, hydrothermally altered graywacke
STC-089	Serpentinite unit, magnesite
STC-099	Franciscan Complex, hydrothermally altered graywacke
STC-102a	Franciscan Complex, manganese ore
STC-103	Franciscan Complex, hydrothermally altered graywacke
STC-104	Franciscan Complex, silica-carbonate rock
STC-105	Panoche Formation (Adobe Flat Shale Member), hydrothermally altered sandstone
STC-112b	Franciscan Complex, manganese ore
STC-113	Franciscan Complex, manganese ore
STS-(01-1-1)	Ione Formation or Valley Springs Formation, claystone
STS-(09-1-11)	Ione Formation, claystone
STS-(21-1-22)	Ione Formation, claystone
STS-(29-1-28)	Ione Formation, claystone
STS-(34-1-34)	Ione Formation, claystone
STS-005	Ione Formation, sandstone
STS-006	Ione Formation, claystone
STS-007	Ione Formation, claystone
STS-015	Gopher Ridge Volcanics, mineralized zone
STS-016	Gopher Ridge Volcanics, mineralized zone
STS-027	Gopher Ridge Volcanics, hydrothermally altered volcanic rock
STS-032a	Ione Formation, sandy siltstone
STS-032b	Ione Formation, claystone
STS-032c	Ione Formation, claystone
STS-035	Ione Formation, claystone
STS-039	Gopher Ridge Volcanics, altered metavolcanic rock
STS-044	Gopher Ridge Volcanics, hydrothermally altered volcanic rock
STS-046	Ione Formation, claystone
STS-047	Gopher Ridge Volcanics, hydrothermally altered volcanic rock
STS-049	Ione Formation, sandstone
STS-052b	Ione Formation, claystone
STS-RR	Ione Formation, claystone

CRO - Coast Range Ophiolite

TABLE B-1

(30-ELEMENT ICP ANALYSIS + Hg)

MAP NO.	ELEMENT SAMPLES	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm	Hg ppb
6	STC-002b	1	10	2	15	.1	2299	108	607	4.42	7	5	ND	1	1	.4	2	3	7	.05	.001	2	193	21.91	1	.01	12	.08	.01	.01	1	-
7	STC-005	1	3	2	32	.1	1297	133	877	5.91	6	5	ND	1	1	.2	2	6	1	.08	.001	2	16	25.88	5	.01	15	.02	.01	.01	1	-
12	STC-056	1	27	9	74	.3	63	25	1101	4.35	7	5	ND	1	21	.7	2	2	98	2.38	.012	2	109	2.92	26	.12	6	2.62	.10	.05	2	-
11	STC-059	1	2	4	11	.1	3	1	47	.30	2	5	ND	1	5	.2	2	2	2	.14	.001	2	3	.03	1	.01	3	.03	.01	.01	1	-
11	STC-059	1	2	7	12	.1	3	1	55	.34	4	5	ND	1	5	.2	2	5	3	.17	.001	2	4	.07	7	.01	7	.05	.01	.01	1	-
26	STC-074	1	8	8	32	.1	17	7	313	1.50	2	5	ND	7	122	.2	2	2	14	1.37	.032	25	11	.10	59	.01	11	.43	.02	.17	1	40
24	STC-075a	1	17	5	16	.1	8	2	61	1.19	2	5	ND	1	6	.2	2	5	10	.03	.010	2	9	.01	24	.01	3	.06	.01	.01	1	25
28	STC-077	1	5	15	27	.1	11	5	294	1.31	7	5	ND	5	85	.2	2	2	12	1.62	.026	19	11	.41	80	.01	19	.40	.03	.18	3	2160
25	STC-079	2	11	7	35	.1	21	6	203	1.48	4	5	ND	3	127	.2	2	2	11	1.36	.042	6	16	.42	64	.01	8	.32	.04	.13	1	370
16	STC-099	5	15	2	44	.1	18	8	316	2.74	111	5	ND	4	52	.2	15	2	29	.21	.044	21	38	.09	428	.01	11	.33	.00	.22	18	377000
14	STC-103	1	8	16	40	.5	2	3	26	3.39	74	5	ND	2	16	.2	8	4	11	.03	.006	10	13	.06	97	.01	16	.31	.00	.37	42	14600000
13	STC-104	1	3	2	17	.1	1380	70	199	1.98	7	5	ND	2	1117	.3	2	2	2	7.08	.001	3	221	10.58	138	.01	6	.04	.01	.01	6	16000
10	STC-105	3	27	4	90	1.5	54	11	110	7.41	40	5	7	5	140	.2	15	2	30	.12	.055	15	34	.14	126	.01	20	.40	.17	.40	48	6100000
3	STC-108	1	6	2	30	.1	1770	112	1033	5.18	21	5	ND	2	152	.7	2	2	5	16.74	.011	2	439	2.03	371	.01	10	.04	.01	.01	2	33000
43	STS-027	2	55	13	81	.1	8	1	147	1.14	2	5	ND	1	14	.2	2	2	2	.08	.020	6	9	.08	100	.11	2	.32	.06	.05	1	-
31	STS-044	1	34	2	35	.1	20	7	36	9.04	2	5	ND	2	31	.2	2	3	16	.14	.044	3	6	.07	33	.04	5	.48	.04	.07	1	-
44	STS-047	1	137	2	113	.1	4	4	364	3.11	3	5	ND	2	10	.2	2	2	2	.02	.026	2	10	.13	132	.01	7	1.03	.01	.10	2	-
44	STS-047	1	147	2	117	.9	6	6	374	3.26	5	5	ND	2	10	.2	2	2	2	.03	.028	2	13	.14	138	.01	10	1.07	.01	.10	4	-

ND - not detected

TABLE B-2

(WHOLE-ROCK ANALYSIS)

MAP NO.	ELEMENT SAMPLES	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	Cr_2O_3 %	Ba ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm	LOI %	[SO_3 [%	CO_2] %]	SUM %
6	STC-002b	37.32	.76	8.12	45.95	.90	.05	.05	.01	.11	.11	.338	5	10	5	5	5	6.3			99.96
6	STC-002b	38.27	.75	7.96	45.06	.88	.05	.05	.01	.11	.11	.331	5	10	5	5	5	6.3	.08	.18	99.82
7	STC-005	31.35	.08	8.83	46.56	.16	.05	.05	.01	.09	.13	.346	5	10	5	5	5	12.5			100.05
7	STC-005	32.31	.08	8.66	45.66	.16	.05	.05	.01	.09	.13	.339	5	10	5	5	5	12.5	.02	.36	99.93
17	STC-014a	76.49	7.39	1.95	.74	.69	.41	.56	.31	.03	.01	.010	429	86	5	16	5	11.3	.01	.02	99.98
4	STC-023	1.13	.08	.15	46.71	.78	.05	.05	.01	.10	.01	.002	5	10	5	5	5	51.1	.36	33.59	100.11
4	STC-023	1.17	.08	.16	46.85	.81	.05	.05	.01	.10	.01	.002	5	10	5	5	5	51.1			100.33
22	STC-035	76.99	8.64	2.90	1.38	.81	1.25	2.41	.29	.09	.02	.006	1159	874	32	5	5	4.9	.01	.03	99.99
20	STC-037	90.09	4.55	1.04	.62	.04	.11	1.39	.56	.04	.03	.007	450	56	192	5	5	1.4	.01	.06	99.99
18	STC-040c	78.89	5.23	2.33	.71	.32	.24	.44	.22	.14	.01	.011	137	25	5	6	5	11.4	.01	.05	99.97
19	STC-045a	70.78	10.09	1.74	2.59	.57	.39	.81	.46	.06	.01	.009	252	48	5	9	10	12.4	.10	1.59	99.96
19	STC-045a	72.47	10.13	2.55	1.75	.54	.38	.84	.47	.06	.01	.015	258	50	5	9	10	10.7	.06	.24	99.97
11	STC-059	98.57	.34	.38	.06	.17	.05	.05	.01	.01	.01	.002	5	10	5	5	5	.4	.08	.09	100.01
11	STC-059	98.75	.38	.39	.05	.19	.07	.05	.01	.02	.01	.002	5	11	5	5	5	.2	ND	ND	100.07
23	STC-064a	88.72	6.69	.52	.15	.04	.05	.19	.21	.01	.01	.002	37	12	51	5	5	3.4	.02	.02	99.99
21	STC-069b	59.60	17.74	5.28	1.40	.81	.22	.30	.63	.07	.01	.005	530	122	209	49	10	13.7	.02	.04	99.91
27	STC-071	61.57	14.74	3.72	2.87	4.01	3.69	2.45	.43	.14	.07	.023	932	751	36	13	10	6.0	.43	2.33	99.97
29	STC-089	1.35	.12	.06	46.79	.82	.05	.05	.01	.12	.01	.002	5	10	5	5	5	51.1			100.36
29	STC-089	1.30	.12	.06	46.62	.79	.05	.05	.01	.12	.01	.002	5	10	5	5	5	51.1	.47	29.34	100.11
36	STS-005	75.24	16.08	1.01	.13	.09	.08	.27	.64	.04	.01	.015	89	15	230	10	10	6.3	.02	.05	99.95
36	STS-006	65.85	20.08	2.11	.34	.28	.34	.60	1.39	.07	.01	.008	17	36	190	93	10	9.4	.03	.12	100.52
36	STS-006	65.42	20.19	2.07	.35	.22	.30	.63	1.40	.07	.01	.007	16	35	179	92	10	9.4	.04	.14	100.10
36	STS-007	63.03	22.57	2.13	.27	.19	.29	.24	1.31	.06	.01	.009	10	26	181	85	10	9.7	.02	.12	99.84
42	STS-032a	72.07	17.25	1.51	.32	.10	.05	.43	.93	.06	.01	.144	322	23	161	10	10	7.0	.02	.05	99.94
42	STS-032b	70.51	18.32	1.45	.30	.17	.05	.27	.91	.05	.01	.076	275	23	171	10	10	7.9	.01	.15	100.06
42	STS-032c	68.98	18.69	2.17	.38	.16	.07	.39	.87	.09	.02	.097	294	29	203	34	10	7.9	.01	.09	99.90
40	STS-035	70.00	18.68	1.35	.27	.16	.05	.06	.89	.05	.01	.011	1034	34	219	18	10	8.3	.03	.16	99.98
40	STS-035	70.59	18.40	1.35	.26	.15	.05	.06	.88	.04	.01	.013	90	30	219	16	10	8.2	.02	.14	100.04
35	STS-039	82.32	11.79	.41	.14	.06	.95	.38	.11	.04	.01	.002	409	47	121	67	10	3.2	.01	.03	99.50
33	STS-046	61.38	16.80	10.30	.33	.12	.05	.97	.89	.10	.01	.034	388	28	196	10	13	8.9	.02	.23	99.98
37	STS-049	83.61	9.82	1.18	.07	.09	.05	.06	.21	.04	.01	.006	5	17	64	10	10	4.5	.01	.04	99.54
34	STS-(1-1-1)	59.41	18.01	6.96	1.35	1.61	1.58	1.70	.84	.07	.07	.008	954	222	214	27	10	8.2	.02	.07	100.03
32	STS-(9-1-11)	66.95	19.06	1.75	.44	.38	.27	2.04	.95	.06	.01	.015	851	107	235	19	12	8.0	.03	.24	100.12
38	STS-(21-1-22)	60.76	21.40	4.02	.42	.26	.19	.83	1.15	.09	.01	.034	456	54	193	30	10	10.7	.02	1.04	99.98
41	STS-(29-1-28)	70.44	17.82	1.83	.26	.16	.11	.39	.92	.06	.01	.025	808	54	176	48	10	7.9	.08	.23	100.10
39	STS-(34-1-34)	72.19	16.97	1.43	.14	.16	.09	.06	1.21	.05	.01	.008	10	18	149	10	10	7.7	.03	.13	99.98
33	STS-RR	65.39	19.05	1.04	.17	.14	.05	.15	1.04	.06	.01	.010	311	18	170	32	10	12.9	.02	3.12	100.09

TABLE B-3

(16-ELEMENT ASSAY)

MAP NO.	ELEMENT SAMPLE	Mo %	Cu %	Pb %	Zn %	Ag oz/t	Ni %	Co %	Mn %	Fe %	As %	U %	Th %	Cd %	Sb %	Bi %	Au oz/t
30	STS-015	.001	.005	.01	.01	.04	.001	.003	.01	14.52	.01	.01	.01	.001	.01	.01	.001
30	STS-016	.001	.001	.01	.01	.01	.001	.002	.11	5.18	.01	.01	.01	.001	.01	.01	.001
30	STS-016	.001	.002	.01	.01	.01	.001	.002	.11	5.09	.01	.01	.01	.001	.01	.01	.001

TABLE B-4

(METAL ASSAY)

MAP NO.	ELEMENT SAMPLES	Mn %	Ni %	Cr %
8	STC-011		.068	31.37
8	STC-011		.070	31.30
9	STC-018b		.252	3.77
5	STC-020		.042	23.53
15	STC-102a	29.98		
1	STC-112b	53.30		
2	STC-113	47.46		

TABLE B-5

(FIRE ASSAY)

MAP NO.	ELEMENT SAMPLES	Au oz/t	Ag oz/t
10	STC-105	.047	.01
31	STS-044	.001	.02
44	STS-047	.001	.02
44	STS-047	.001	.03

TABLE B-6

ESTIMATED WEIGHT PERCENTAGES OF MINERALS IN SELECTED TERTIARY CLAY AND SANDSTONE SAMPLES

SAMPLE NO.	QUARTZ (wt.%)	KAOLINITE (wt.%)	COMMENTS
STS-5	56.3	40.7	Ione sandstone in Curtoni Pit
STS-6	42.2	50.8	Ione claystone in Curtoni Pit
STS-7	36.4	57.2	Ione claystone in Curtoni Pit
STS-32a	51.7	43.7	Ione siltstone
STS-32b	48.9	46.4	Ione claystone
STS-32c	47.3	47.3	Ione claystone
STS-35	48.9	46.6	Ione claystone in Kraftile Pit
STS-39	68.4	29.9	Altered metavolcanic rock; minor feldspar
STS-49	67.8	33.9	Ione sandstone; minor feldspar?
STS-(01-1-1)	11.0	1.3	50-55' interval; 42% smectite, 33% illite, 14% albite, Ione? Valley Springs?
STS-(09-1-11)	26.6	22.7	20-25' interval; 13.7% smectite, 40% illite; weathered crystalline basement?
STS-(21-1-22)	35.5	54.2	35-40' interval; Ione claystone
STS-(29-1-28)	49.4	45.1	55-60' interval; Ione claystone
STS-(34-1-34)	52.2	43.0	40-45' interval; Ione claystone
STS-RR	41.5	45.6	Ione claystone in 49er Pit; 5.3% smectite; high organic content
STC-14a	27	0	Kreyenhagen diatomite; 35% smectite, 35% opal; results highly uncertain
STC-37	82	8	Tesla sandstone; 8% K-feldspar; results somewhat uncertain
STC-40c	4	0	Kreyenhagen diatomite; 27% smectite, 67% opal; results somewhat uncertain
STC-64a	81	17	Poverty Flat sandstone; results reasonably certain
STC-69b	*	23	Valley Springs claystone; 44% smectite, 33% glass*; results highly uncertain

The above weight percentages are approximations only, calculated from whole-rock chemical analyses in Table B-2. Assumed chemical compositions were used for the following minerals: Quartz-SiO_2, Kaolinite-$Al_4[Si_4O_{10}](OH)_8$, K-feldspar-$KAlSi_3O_8$, Albite-$NaAlSi_3O_8$, Opal-$SiO_2 \cdot nH_2O$. The formulas for smectite and illite were adapted and modified from Deer and others (1966). The assumed chemical compositions of smectite, feldspars, and opal (8% water) may result in large errors. The principal minerals present in each sample were determined or inferred by x-ray diffraction.

TABLE B-7

BRIGHTNESS MEASUREMENTS

Brightness measurements were made for three clay-rich diatomite samples, with results as follows:

SAMPLE NO.	*BRIGHTNESS (in percent reflectance)			
	** -400 mesh		*** SPEX BALL MILL	
	packed	not packed	packed	not packed
STC-14a	75.5	72.5	74.1	72.2
STC-31	79.4	77.0	78.2	76.1
STC-40c	73.3	71.2	71.7	70.4

* Brightness was determined using a Photovolt Model 577 reflectance and gloss meter with a "T" search unit and a green tristimulus filter.

** A -400 mesh particle size fraction was obtained for each sample by wet sieving the sample through a 400-mesh nylon screen. Before sieving, each sample had been pulverized for 10 minutes in a Spex ball mill using a ceramic sample holder and ball. Samples were packed by using a cylindrical insert slightly smaller than the inside diameter of the sample curvette, with a 1 kg weight placed on top. The "not packed" samples were loaded into the sample curvettes and tapped slightly to eliminate large voids.

*** "SPEX ball mill" samples were pulverized and packed or not packed as previously described without sieving; some +400 mesh particles are present.

FIGURE B-1. – Comparison of X-ray diffraction patterns for samples of claystone from the Ione Formation in Stanislaus County (patterns a through f) with those in Amador County (g) and Placer County (h). Sample numbers are listed at the top of each pattern. Locations of samples are given in Figures B-3 through B-10, which are enlargements of each pattern.

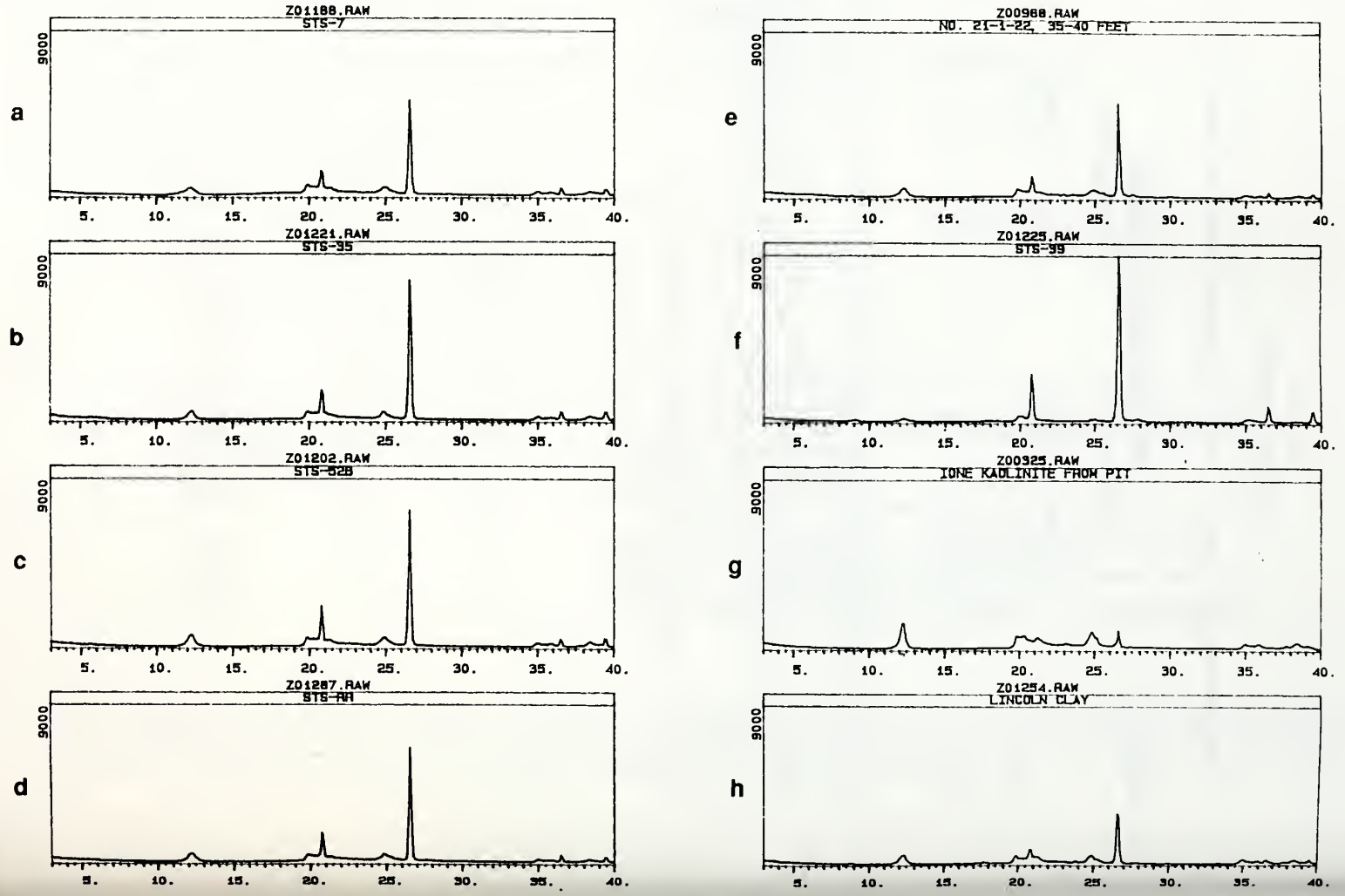


FIGURE B-2. – Comparison of X-ray diffraction patterns for samples of sandstone from the Ione Formation (a) and Poverty Flat Sandstone (b) in Stanislaus County. Sample numbers are listed at the top of each pattern. Locations of samples are given in Figures B-11 and B-12, which are enlargements of each pattern.

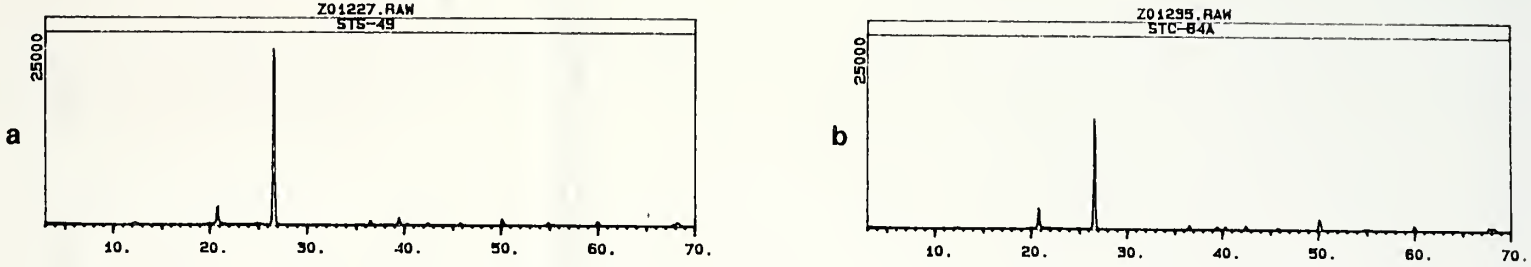


FIGURE B-3. – X-ray diffraction pattern of claystone (sample STS-7) from Curtoni Pit, Stanislaus County (map Number 36 on Plate 8C).

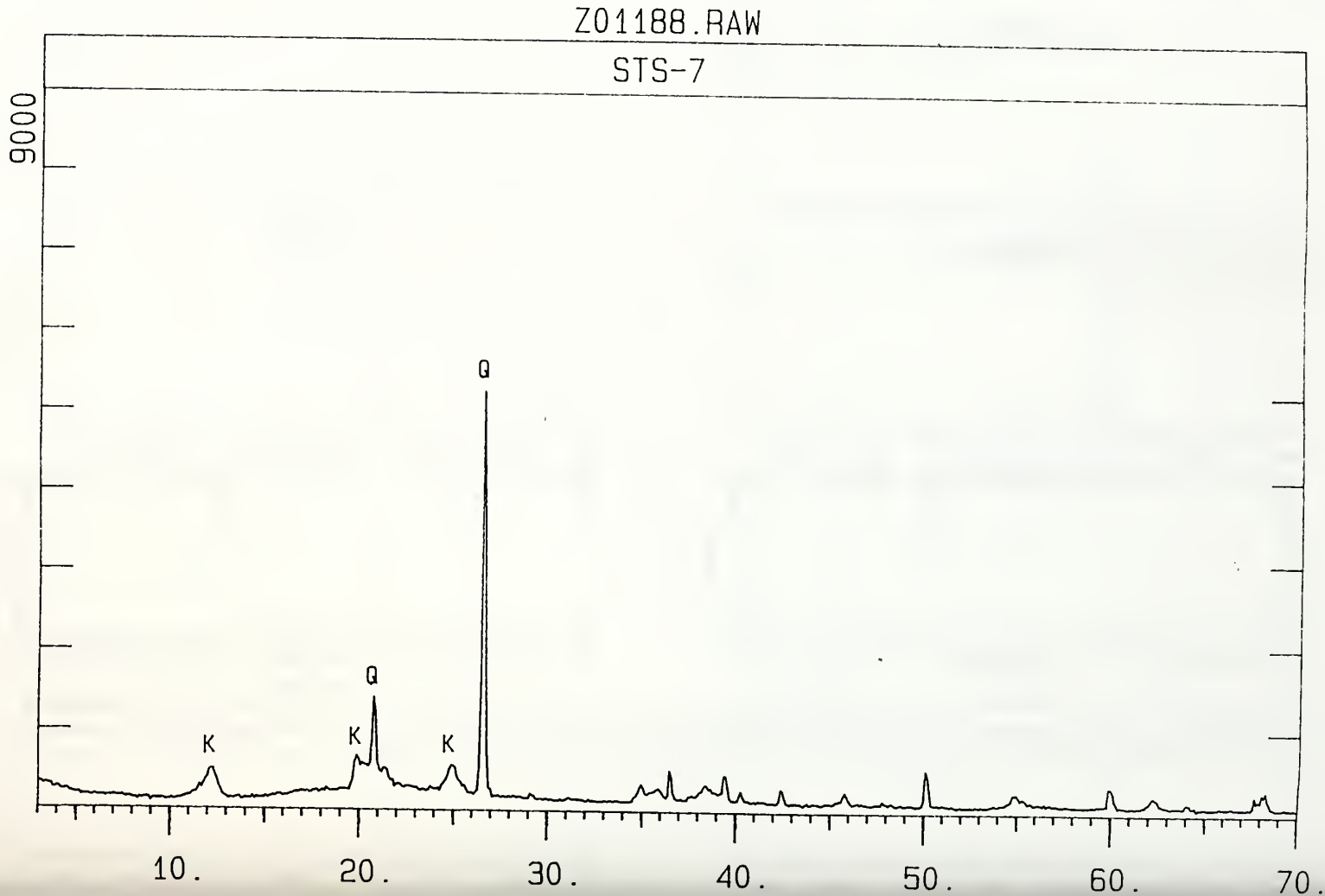


FIGURE B-4. – X-ray diffraction pattern of claystone (sample STS-35) from Kraftile Pit, Stanislaus County (Map Number 40 on Plate 8C).

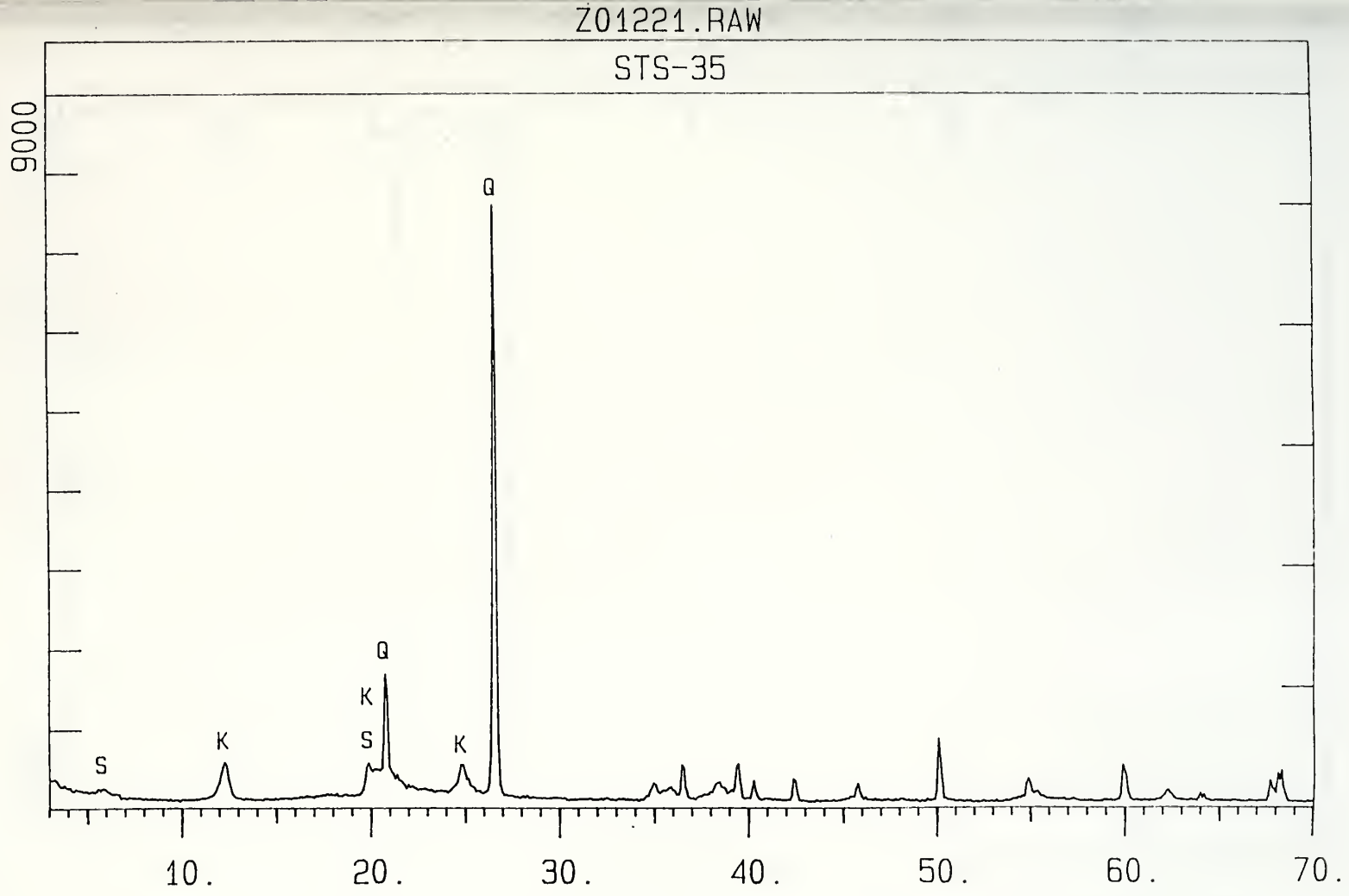
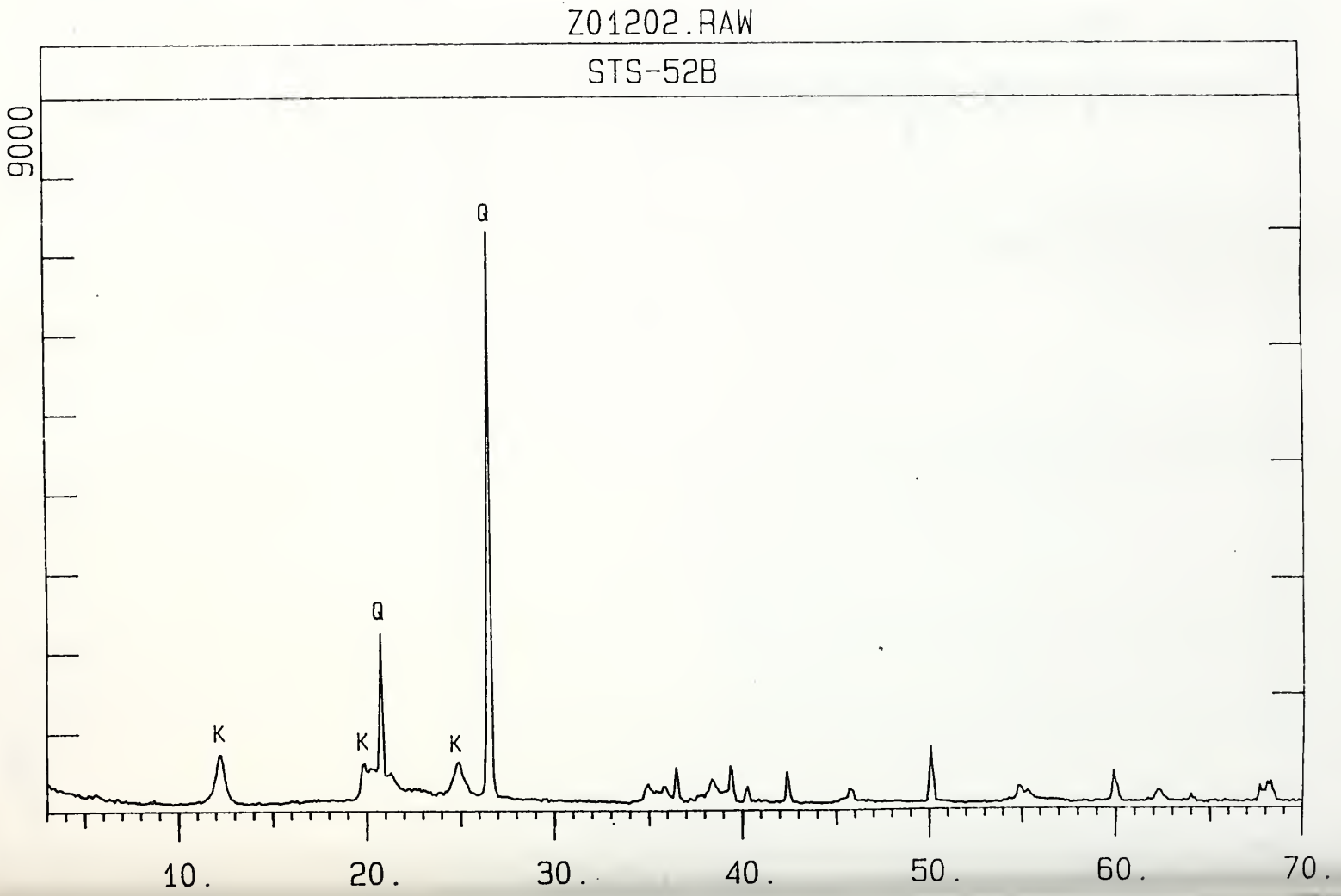


FIGURE B-5. – X-ray diffraction pattern of claystone (sample STS-52b) from Winkler Pit, Stanislaus County (Mine Number 149 on Plate 8C).



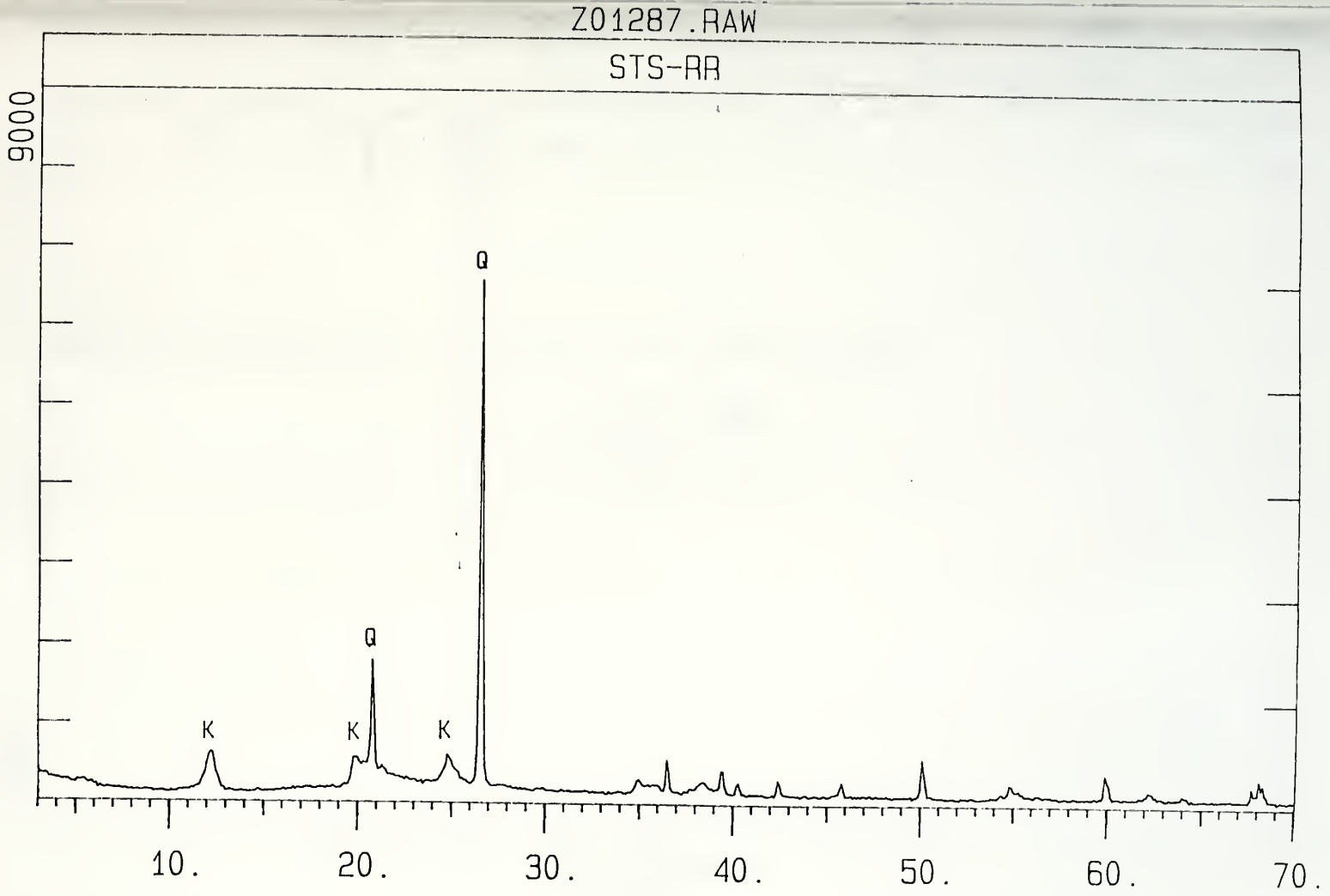

Z01287.RAW
STS-RR
9000
Q
Q
K
K
K
10.
20.
30.
40.
50.
60.
70.

FIGURE B-7. – X-ray diffraction pattern of claystone (sample STS-21-1-22) from drill hole number 21 at 35-40-foot interval, Stanislaus County (Map Number 38 on Plate 8C).

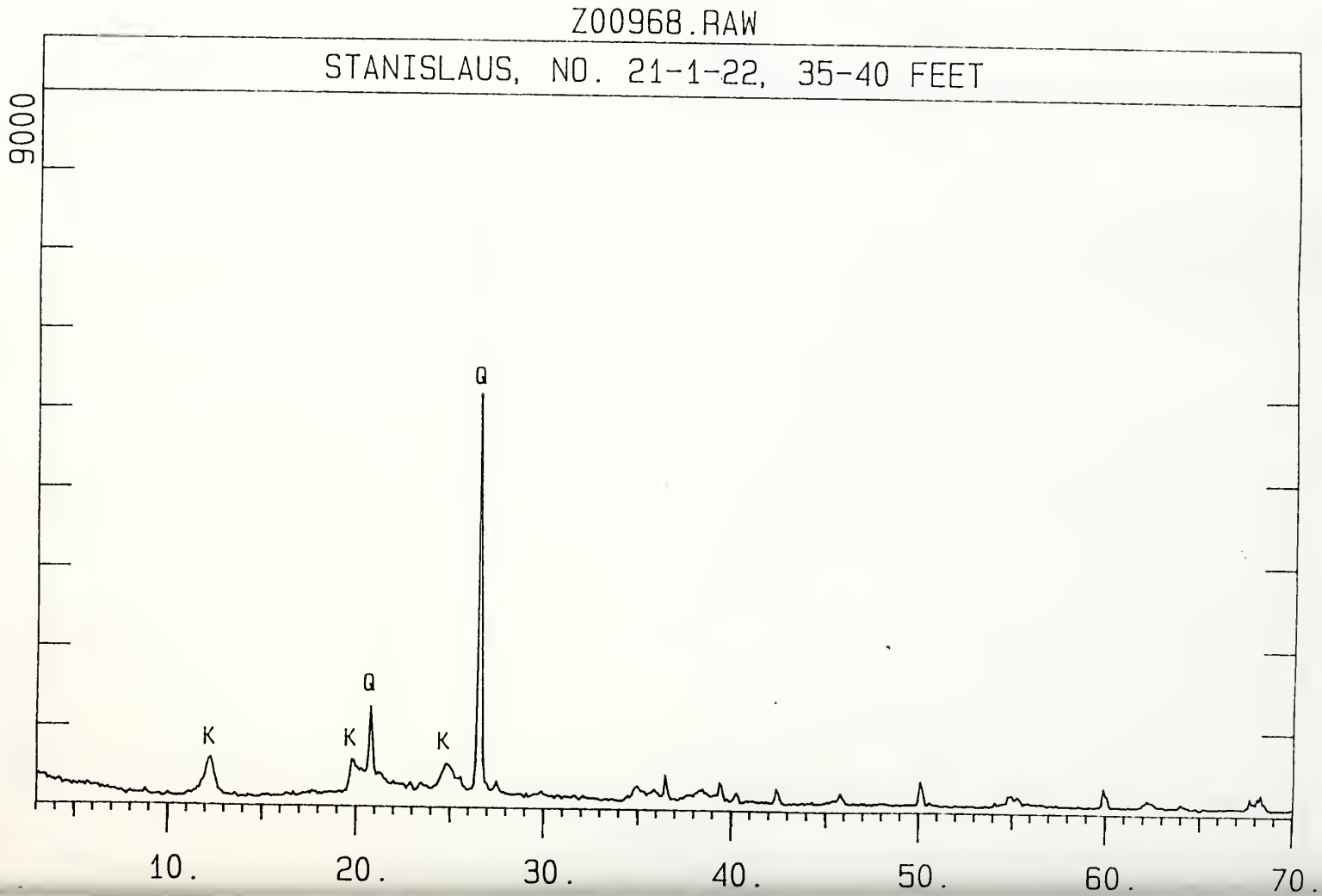


FIGURE B-9. – X-ray diffraction pattern of claystone from a commercial pit, Ione, Amador County.

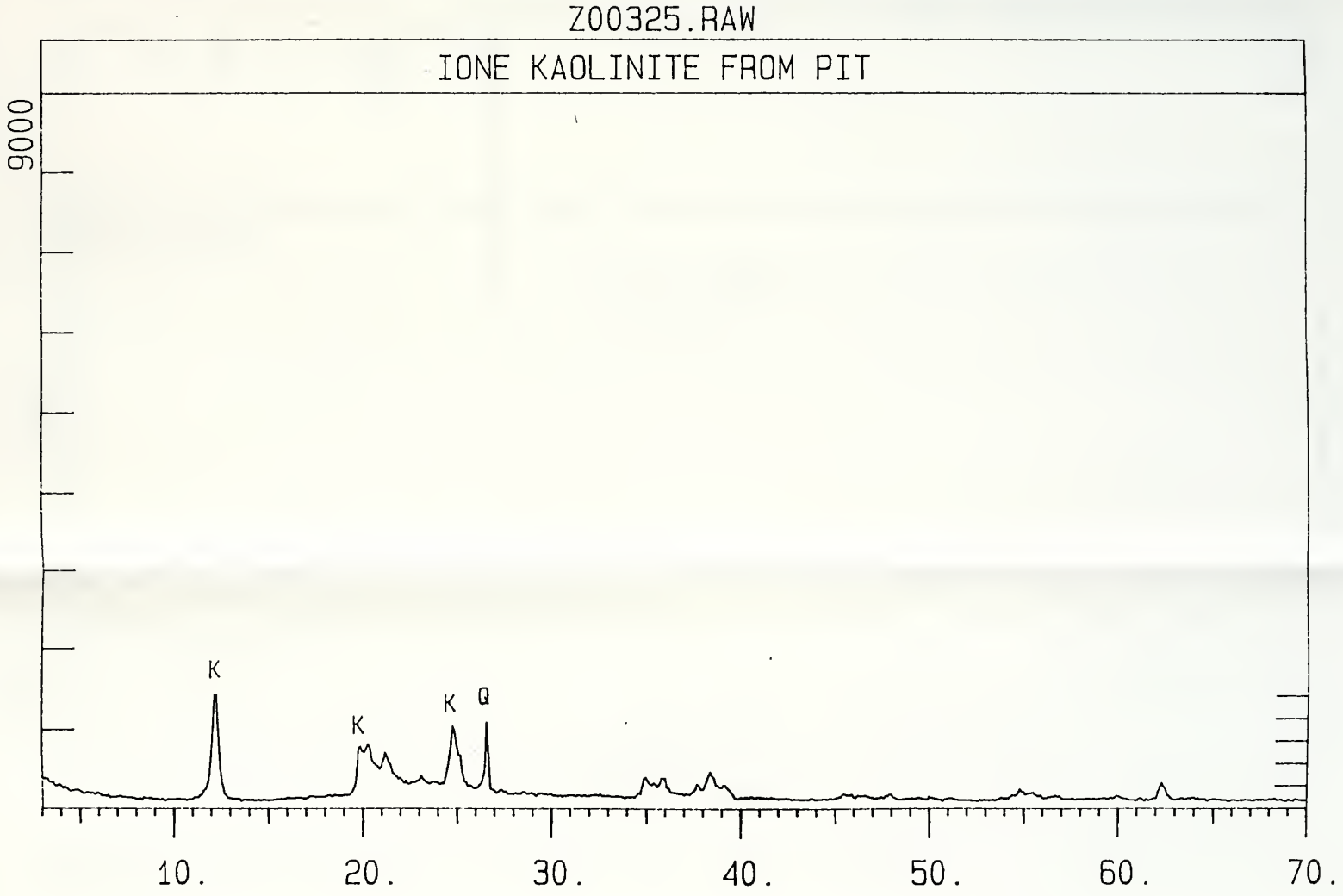


FIGURE B-10. – X-ray diffraction pattern of claystone from a commercial pit, Lincoln, Placer County.

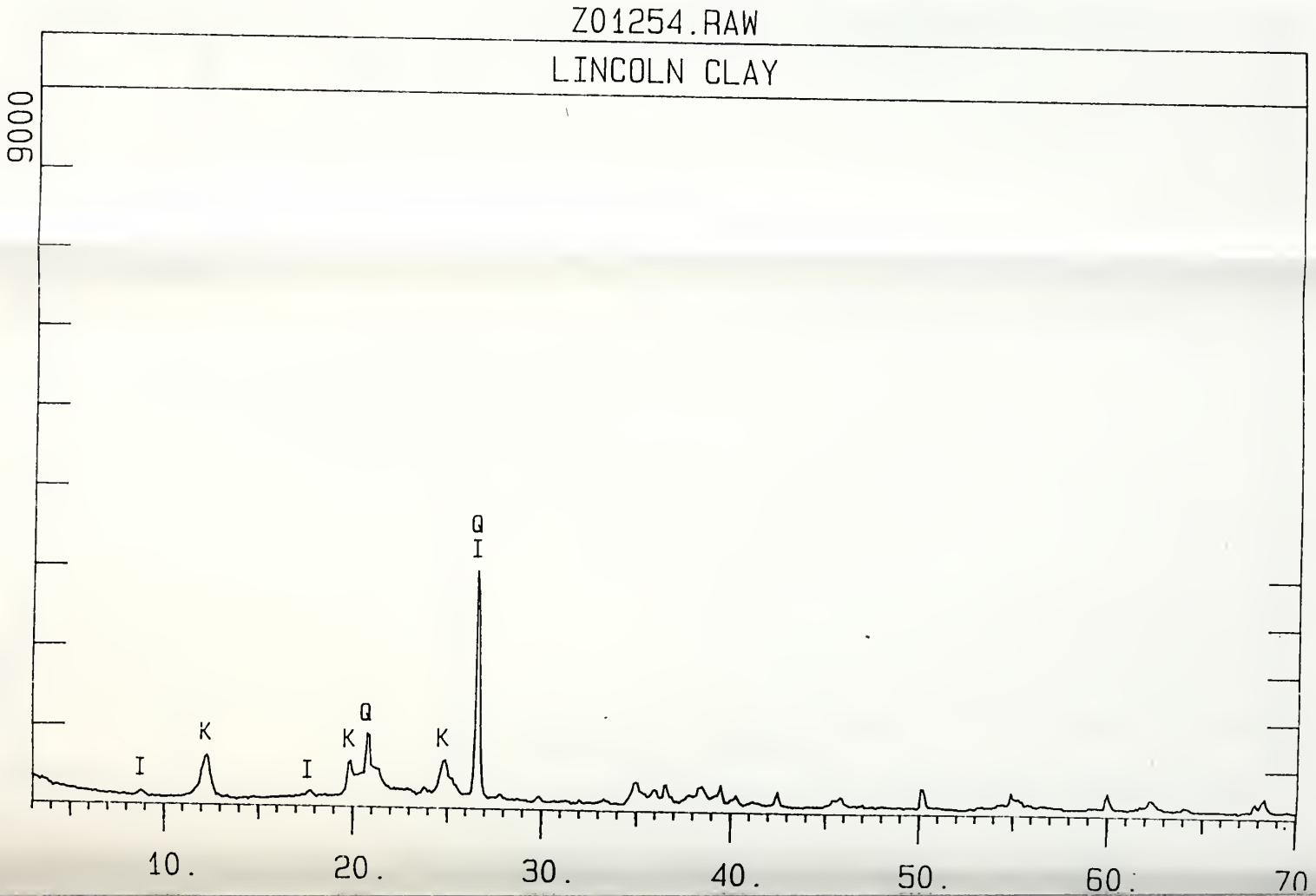


FIGURE B-11. – X-ray diffraction pattern of sandstone (sample STS-49) from an outcrop south of Cooperstown, Stanislaus County (Map Number 37 on Plate 8C).

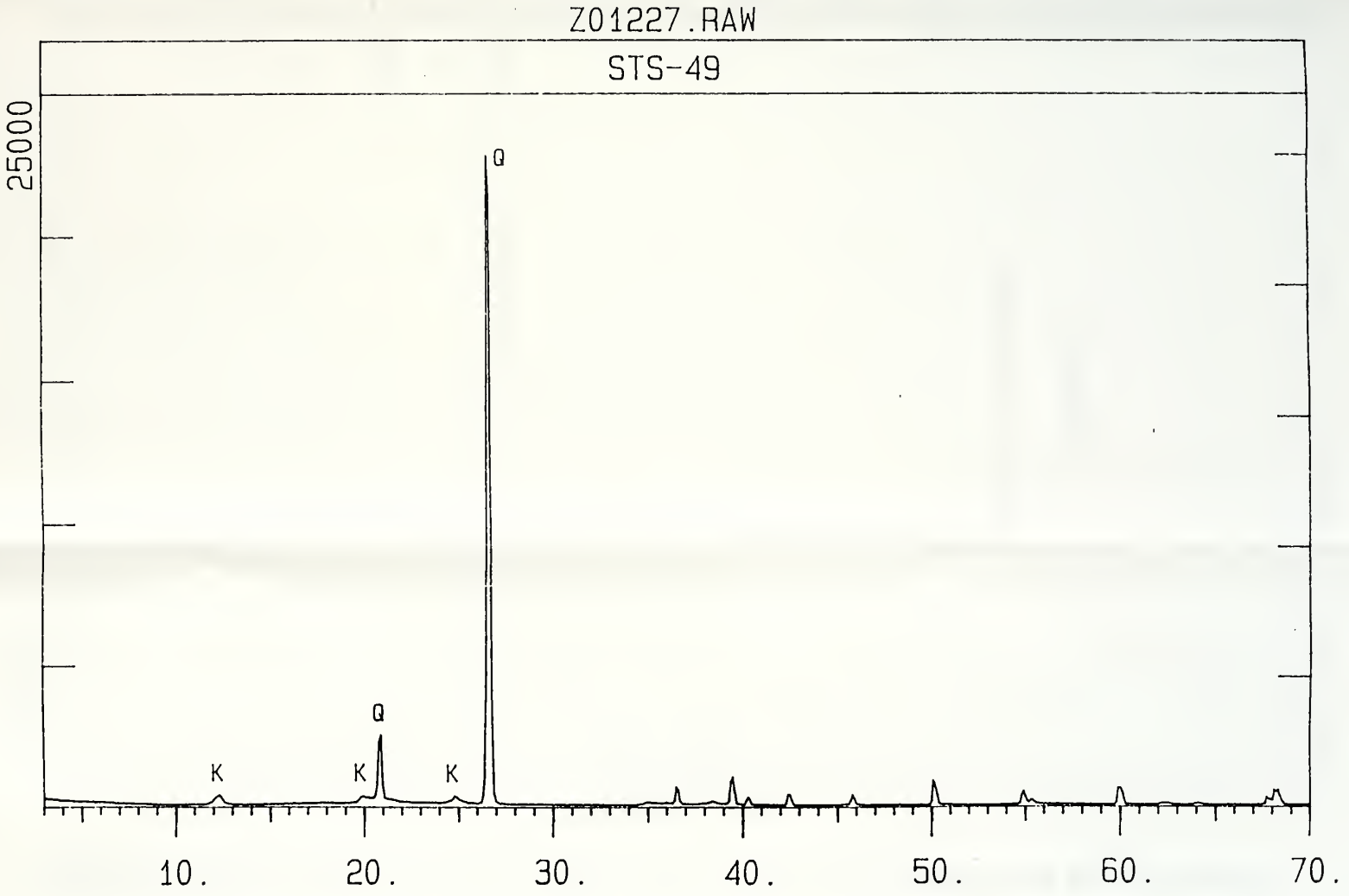
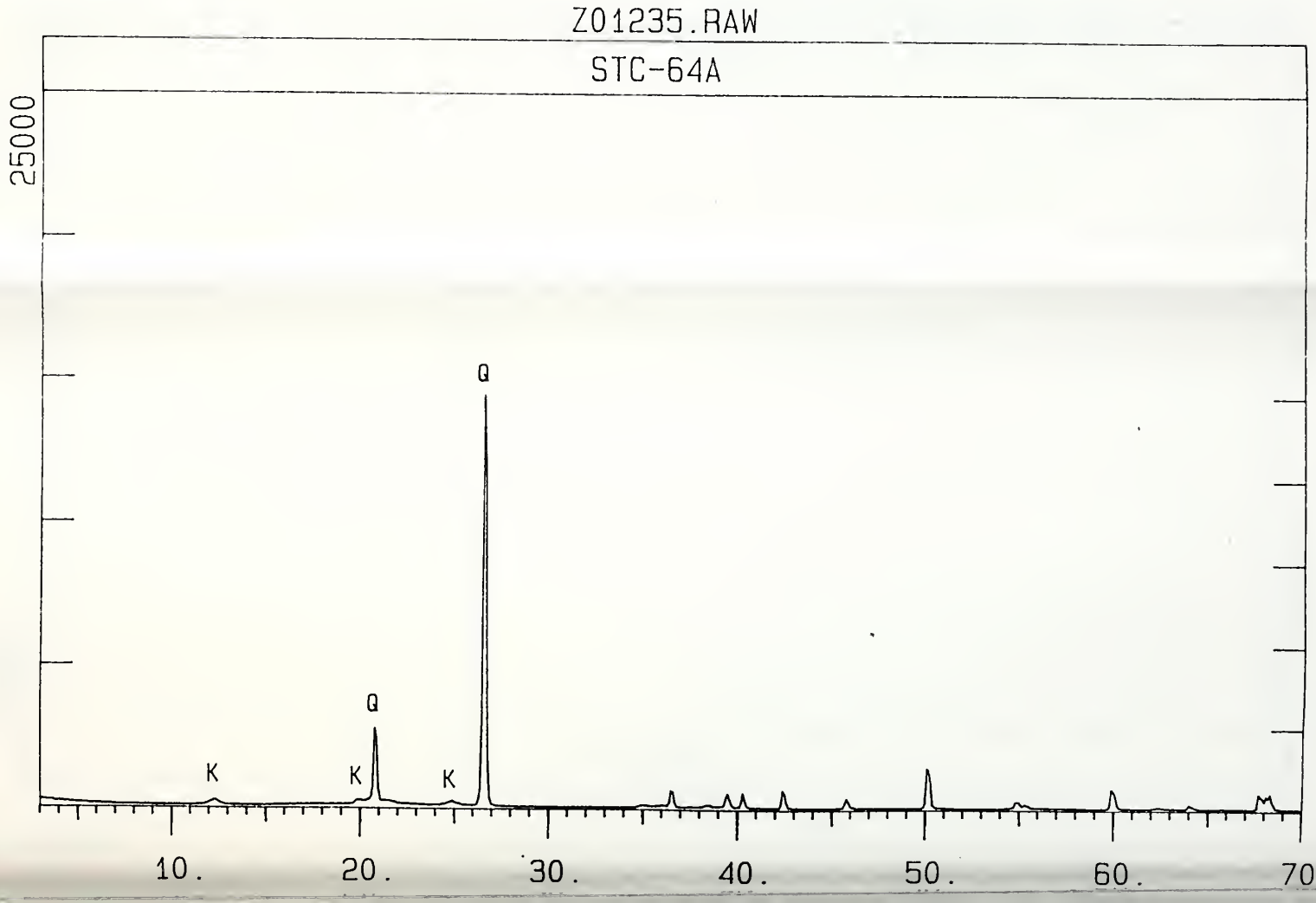


FIGURE B-12. – X-ray diffraction pattern of sandstone (sample STC-64a) from an outcrop south of Orestimba Creek, Stanislaus County (Map Number 23 on Plate 8A).



APPENDIX C

Geophysical Studies

INTERPRETATION OF GRAVITY, MAGNETIC, AND SEISMIC REFRACTION DATA IN STANISLAUS COUNTY AND VICINITY, CALIFORNIA

(Modified from Chapman and others, in preparation)

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INTRODUCTION

As part of the mineral land classification study of Stanislaus County, geophysical data of various kinds available in the area were reviewed, with additional data collected in the field to supplement them. The new data consist of gravity, magnetic, and seismic refraction measurements obtained in various parts of the county for different purposes. Several interpretive maps were prepared, which have revealed additional, mostly local, geologic features of the study area. These features can be important aids for the discovery and understanding of associated mineral deposits. Technical details on the geophysical surveys are presented in Chapman and others (in preparation).

GRAVITY DATA

Gravity data were obtained from the compilations by Robbins and others (1974; 1976b), Snyder and others (1982) and Andrew Griscom (U.S. Geological Survey, personal communication, 1992), supplemented by an additional 269 stations obtained during the present study (Chapman and others, in preparation). These data were combined to prepare new gravity maps for the entire study area. Plate 9 is a Bouguer gravity map of the county, contoured with a two milligal (mGal) interval.

REGIONAL GRAVITY FEATURES

Regional gravity anomalies on the San Jose 1:250,000-scale map sheet, which includes Stanislaus County, have been describe by Robbins and others (1976a). The major regional gravity features, which can also be observed on Plate 9 and on the Isostatic Residual Gravity Map of California (Roberts and other 1991), include relatively high values in parts of the Coast Ranges, a low along the west side of the Great Valley, gravity highs in the central and eastern parts of the Great Valley, and prominent low closure centered near Woodward Reservoir, northea of Oakdale.

The high gravity values in the Coast Ranges are clearly associated with rocks of the Franciscan Complex, which include relatively high-density metamorphosed graywacke, volcanic rock (greenstone), and chert (Chuchel and Jachens, 1990). The low ov the west side of the Great Valley (and adjacent foothills) is believed to be associated with the uppermost Jurassic to Quaternary sediments and sedimentary rocks that fill the valley to a depth of about 4 to 7 miles (Oliver and Griscom, 1980). The axis of the gravity low probably does not exactly overlie the axis of the San Joaquin Valley Syncline, but may lie somewhat east of it because the younger formations have the greatest thicknesses and density contrasts, and have axes progressively farther east with decreasing age (Robbins and others, 1976a). That part of the negative anomaly represented by the -60 Mgal contour west of Newman in the southwestern part of the county probably is enhanced by the thick deposits of low-density diatomite of the Kreyenhagen Shale in this area.

The positive gravity anomaly that trends southeastward approximately parallel to the axis of the Great Valley passes through Modesto and Turlock and is part of the feature known as the Great Valley gravity high (Oliver and Griscom, 1980). This anomaly, which is associated with a magnetic high in the area, i believed by Oliver and Griscom (1980) to be caused by a tectonically emplaced fragment of oceanic crust (ophiolite). Nea Turlock, there is a very prominent eastward "bulge" in the anomaly which includes a positive -20 mGal closure centered in Merced County, a few miles south of the Stanislaus County line (Robbins and others, 1976a).

An areally large negative gravity anomaly is centered southeast of Woodward Reservoir, northeast of Oakdale. The cause of this anomaly is not known, but it could represent a granitic intrusion, possibly a stock, in the basement rocks. Similar gravity anomalies are known to be associated with such intrusion in the area east of Chowchilla (Robbins and others, 1976a) and near Rocklin, northeast of Sacramento (Oliver and others, 1985). The central part of this negative anomaly, however, is within a system of northwest-trending aeromagnetic anomalies that are characteristic of the metavolcanic rocks in the Sierra Nevada foothills (Plate 10). Within this system, a local negative

aeromagnetic anomaly is apparently associated with the central part of the gravity low. The negative magnetic anomaly is offset somewhat to the south of the gravity anomaly, as would be expected. This aeromagnetic low, if real, lends support to the idea of a granitic intrusion. The gravity anomaly northeast of Sacramento also has a corresponding negative aeromagnetic anomaly (Youngs, 1988). The negative aeromagnetic anomaly near Woodward Reservoir is partly surrounded by positive anomalies that trend in various directions and are not necessarily the normal northwest-trending features of the foothill area. Perhaps some of these positive anomalies represent metamorphic or alteration zones in the older metamorphic rocks that surround the inferred intrusion. Depths to the intrusion may be about 3,000 feet.

LOCAL GRAVITY FEATURES

Cooperstown-La Grange Area

Relatively detailed gravity data were obtained in portions of the Cooperstown, La Grange and Keystone 7.5-minute quadrangles, in the area that includes the Cooperstown clay deposits near the eastern boundary of Stanislaus County. These show local gravity anomalies that may represent buried basement topography or different types of rocks in the basement. The basement rocks are exposed near the northeastern edge of the county, but are buried beneath younger Tertiary and Quaternary age rocks in most of the area.

The large positive gravity anomaly located east of Turlock appears to extend northward with a reduced amplitude into the Cooperstown area where there is a -30 Mgal closure (Plate 9; Robbins and others, 1976a; Roberts and others, 1991). This gravity high, centered south of Warnerville, probably is not related to the one east of Turlock, however, because the Turlock anomaly has an associated magnetic anomaly and is believed to be caused by a fragment of oceanic crust. In contrast, the Warnerville anomaly is crossed at an angle by a number of northwest-trending magnetic anomalies (both positive and negative) that are characteristic of the metavolcanic rocks in the foothill area (Plate 10).

Plate 9 shows a westward-trending local negative gravity anomaly, indicated by a flexure in the gravity contours, somewhat north of the Tuolumne River, between the town of La Grange and a point west of Modesto Reservoir. In the vicinity of La Grange, the low gravity values appear to be associated with the Merced Falls Slate, which is exposed both in this area and farther southeast. The western extension of the anomaly, however, probably is not caused by a west-trending slate zone, but appears to represent a buried valley cut into the basement. To cause this anomalous density contrast, the ancestral Tuolumne River must have excavated its course in the basement rocks. Subsequently, the river valley was filled with younger sedimentary rocks. A

2600-foot-deep petroleum exploration drill hole (Plate 11), which apparently did not encounter basement, is evidence that this buried valley is present. The minimum depth indicated by this drill hole is much deeper than the depth for basement in this area indicated by Bartow (1983).

To study local gravity anomalies in this area, it was necessary to make a residual gravity map (Plate 11) because of the steep gravity gradient here, which is believed to be caused by the "roots" of the Sierra Nevada. To construct Plate 11, a regional gravity field was first constructed by contouring data from stations that either are known to be on basement metavolcanic rocks or are near drill holes where the depths to basement rocks are known. To do this, the data at two drill holes were adjusted for the approximate effect of thicknesses of Tertiary sedimentary rocks, and then the regional surface was removed from the complete Bouguer gravity values at each station. The results were contoured at a one-Mgal interval. One of the drill holes used for this purpose, situated near Warnerville, was reported to have encountered basement rocks at a depth of about 623 feet (Smith, 1959). The other drill hole, the petroleum exploratory well mentioned above, did not encounter basement rocks, but did provide a minimum depth to basement of 2,600 feet (California Division of Mines, 1943). The residual gravity map may not accurately reflect depths to basement (thicknesses of Tertiary sedimentary rocks and Quaternary alluvial deposits) because of the uncertainties involved, but it may provide at least an indication of the buried basement topography. The lack of reliable subsurface data over much of the study area and possible differences in basement rock densities are uncertainties that must be considered in the final interpretation.

In addition to the anomaly that is believed to represent an ancestral Tuolumne River, Plate 11 shows a pair of anomalies, one positive and the other negative, east of Warnerville. The positive anomaly trends southeastward in the northern part of the area and, in the vicinity of the Cooperstown Road in Sections 29 and 30, T2S, R13E, it turns toward the south. The anomaly decreases in amplitude in this direction and disappears where it encounters the west-trending Tuolumne River negative anomaly. The negative anomaly, which is between the positive anomaly on the west and the exposures of basement rocks on the east, also extends southeast and south from the vicinity of Rock River Road, northwest of Cooperstown, generally through Section 33, T2S, R13E, to where it apparently joins the Tuolumne River negative anomaly somewhere near Section 16, T3S, R13E. This negative anomaly could represent either a buried valley (a possible tributary to the ancestral Tuolumne River) or a relatively low-density layer or zone in the basement rocks. If a buried valley is present, the positive anomaly to the west would represent, at least in part, a buried hill. Drill-hole data from a lignite exploration program in this area (Plate 11) do not confirm the suggestion of buried topography for the source of the anomalies, at least in the area near Rock River Road and Cooperstown where

the negative anomaly trends southeast. It is possible, however, that a buried valley is present southward from near Section 33, T2S, R13E, where the anomaly has a generally southward trend. The facts that the anomaly becomes larger toward the south and that it appears to curve toward the southwest to meet the Tuolumne River negative anomaly tend to support this suggestion. That part of the negative anomaly that trends southeast in the vicinity of Cooperstown may represent rocks that have relatively low densities, such as slate or deeply weathered basement rocks (saprolite). In contrast, the corresponding positive anomaly to the west may represent fresher metavolcanic rocks with relatively high densities.

Profile A-A' (Plate 11) is a northeast-trending residual gravity profile located in an area south of Cooperstown where the gravity data are relatively well represented and where the anomalies may represent, in part, a buried hill and valley. This profile was used to compute a model of the possible buried valley by using a two-dimensional gravity inversion program, assuming the anomalies are caused entirely by a topographic feature in the basement. A density contrast of 0.75 g/cm^3 was used, based on average values of metavolcanic rocks (about 2.85 g/cm^3) and Tertiary sedimentary rocks (about 2.10 g/cm^3) from Chapman and Bishop (1975) and Robbins and others (1976a). The results of using this density contrast are that the residual anomalies shown on the profile are somewhat different than those shown on Plate 11. Because there are no known drill holes near the positive anomaly that may represent the buried hill, the depth to the buried basement ridge was estimated from the gravity data to be about 250 feet. The model shows a broad valley having a depth from the surface of about 600 feet. Drill hole CTN-5, which is near the profile and near the center of the negative anomaly, appears to confirm this maximum depth estimate (Plate 11). The log from this drill hole shows basement rocks at a depth of about 600 feet, and a thickness of about 255 feet of Ione Formation, including some lignite. Drill hole CTN-10, almost two miles to the northwest and just west of the positive gravity anomaly, also shows a thick section of Ione Formation, however.

A number of relatively shallow bucket-drill holes were drilled in the area during a clay exploration program by the U.S. Bureau of Mines and the California Division of Mines and Geology (Padan, 1963). The approximate locations of these drill holes are shown on Plate 11, but most of the holes are not deep enough or the logs too ambiguous to provide information on the depth to basement rocks.

Because of uncertainties in the actual values of local rock densities, possible deep weathering of the basement in places, lack of control from drilling in covered areas, and sparse gravity data in parts of the area, the results of this attempt at modeling is subject to errors. It could be improved when additional data become available.

If there is a buried valley in part of the Cooperstown area as suggested here, conditions may have favored deposition of relatively thick clay beds of the Ione Formation within this feature. A similar but much larger-scale feature is present at the world-class clay deposits to the north at Ione in Amador County (Chapman and Bishop, 1975). Based on the drill-hole data described above, however, it appears that only the southern part of the negative gravity anomaly could represent this feature.

West Side of the Great Valley

On the west side of the Great Valley, where Del Puerto Canyon enters the valley, there is a distinct local gravity high that interrupts the northwest-trending negative anomaly closure that is present along the west side of the valley (Plate 9). The presence in the Del Puerto Creek fan of an abundance of relatively dense metamorphic rocks derived from the Franciscan Complex and Coast Range Ophiolite may cause this local positive anomaly. Gravity contours near Hospital Canyon along the northwestern edge of the map area also show an indication of a possible local positive anomaly. This canyon also drains a large area underlain by the Franciscan Complex. These rocks are more favorable for use as aggregate than the softer sedimentary rocks of the Great Valley Sequence.

Two detailed gravity and magnetic profiles (Chapman and others, in preparation) were run on the western side of the Great Valley, one on the Orestimba Creek fan and the other on the Salado Creek fan. These profiles were made to determine whether they would reveal both the location and amount of vertical offset of the San Joaquin Fault, which is believed to be present in this area (Bartow, 1991). Such offset could have influenced the character and thickness of sand and gravel deposits useful as construction aggregate.

The Orestimba profile was located partly along Stuhr Road in Sections 16 and 17, east of Interstate 5. This profile did not show any obvious offsets or other anomalies that would suggest a fault.

The Salado Creek profile was located along the Oak Flat Road from Ward Road to a point a few hundred feet west of Interstate 5. Close to the California Aqueduct and the inferred location of the fault (Wagner and others, 1990), this profile does show a relatively steep local gradient, that could represent a fault offset. Assuming a density contrast of 0.50 g/cm^3, the gravity offset of about 0.22 mGal would represent a vertical offset of about 45 feet (downward on the east).

Regarding the lack of an apparent anomaly on the Orestimba profile, it is worth noting that the original map by Bartow and others (1985), shows en echelon segments for the fault in this area. Thus, the trace of the fault at least might not cross the

fan in the area where the gravity profile was obtained. The evidence from the gravity data, however, cannot be considered conclusive either for or against the presence of a fault in either of the particular examples discussed here. For example, a strike-slip fault might not show a vertical offset, or even if it does, there may not be a density contrast sufficient to cause an anomaly.

Magnetic profiles were also measured along the gravity profiles at both the Orestimba fan and the Salado Creek fan. In both cases, however, numerous cultural features, including power lines, caused magnetic disturbances that are much larger than any useful geologic information.

MAGNETIC DATA

A mosaic of existing aeromagnetic data was prepared for the entire study area (Plate 10) and several ground magnetic profiles (Chapman and others, in preparation) were obtained to investigate a few aeromagnetic anomalies in more detail.

Aeromagnetic Data

Aeromagnetic data were compiled from several sources (Ponce and Langenheim, 1987; Henderson and others, 1966; Meuschke and others, 1966; Abrams, 1992; and Brabb and Hanna, 1981) for the study area and assembled as Plate 10. Because these sources represent different flight line elevations, spacings, and directions, and because some are total-intensity maps and others are residual maps, they could not be easily merged. Consequently, they are shown on Plate 10 as separate areas, marked off by lines that form the boundaries of individual maps.

Measurements of specimens of various types of pre-Tertiary basement rocks in the Coast Ranges and in the foothills of the Sierra Nevada indicate that serpentinite and serpentinized ultramafic rocks are, by far, the most magnetic (Saad, 1969; DuBois, 1963). Some metavolcanic rocks in the foothills are also moderately magnetic (Henderson and others, 1966), although most of the other basement rocks and the Tertiary sedimentary rocks are believed to be relatively non-magnetic.

In the Coast Ranges of southwestern Stanislaus County, strong positive magnetic anomalies that have various orientations mark the locations of masses of serpentinite or partially serpentinized ultramafic rock. Such rock is host to deposits of chromite and magnesite throughout this part of Stanislaus County. The two major magnetic anomalies in this part of the Coast Ranges (Plate 10) probably are caused by both serpentinite and partially serpentinized ultramafic rock. The larger, northwesternmost composite anomaly was termed the "Red Hill" (probably meant to be "Red Mountain," which we use here) anomaly and the smaller one

was termed the "Orestimba Creek" anomaly by Brabb and Hanna (1981). These authors interpreted each of these anomalies to be caused by serpentinite bodies of "massive proportions." Griscom and Jachens (1991) believed that the two anomalies represent partly exposed antiformal ophiolite masses. It is evident from both the size of these anomalies and the distribution of mapped geologic units (Plate 1A) that the sources of both of these anomalies, particularly the Red Mountain anomaly, must be larger than the exposed serpentinite and other serpentinized rocks. One part of the Red Mountain anomaly, at Copper Mountain, is associated with the Volcanic Member of the Coast Range Ophiolite for example, but this rock unit probably does not cause the anomaly because it is relatively non-magnetic. It is probable, therefore, that serpentinite or serpentinized rocks underlie at depth the exposures of the Volcanic Member. The size and shape of the Red Mountain composite anomaly suggests that there are other unexposed serpentinite masses that also help cause the overall anomaly. Figure C-1 shows an outline of the area thought to include both exposed and concealed masses of serpentinite and ultramafic rock associated with the anomaly.

Detailed ground magnetic data might be used to help locate local serpentinite or ultramafic masses that are either unrecognized or hidden below the surface. This also might be accomplished by enhancing the aeromagnetic data by means of a downward continuation computer program. As mentioned above, such rock might host undiscovered chromite and magnesite deposits in the area.

The gravity map (Plate 9) indicates that there apparently is a negative gravity anomaly associated with the Red Mountain magnetic anomaly. The gravity anomaly has approximately the same shape, is in the same general location, and has an amplitude of about 3 or 4 mGals. The anomalous mass must have an overall low density as well as a high magnetic susceptibility. Thus, both the magnetic and gravity anomalies could be caused by serpentinite.

The eastern side of the Coast Ranges is characterized by magnetic contours that generally follow the topography. A northwest-trending magnetic minimum is present in the eastern part of the range near the gravity minimum, and the magnetic field increases both to the east and west from this. A small, but persistent, magnetic anomaly, which trends north-northwest, follows the trend of the bedding near the magnetic minimum (Plate 10). Abrams (1992) suggests that this anomaly may represent a fault. It could also be a particularly magnetic horizon in the Panoche Formation in this area.

The magnetic field in the Great Valley is dominated by a large, broad, magnetic high, known as the Great Valley High, the axis of which on Plate 10 extends from the vicinity of Ripon, on the north, southeastward through Modesto and Turlock to the southern border of Stanislaus County. In the vicinity of Turlock, the anomaly expands eastward, and there is a magnetic closure

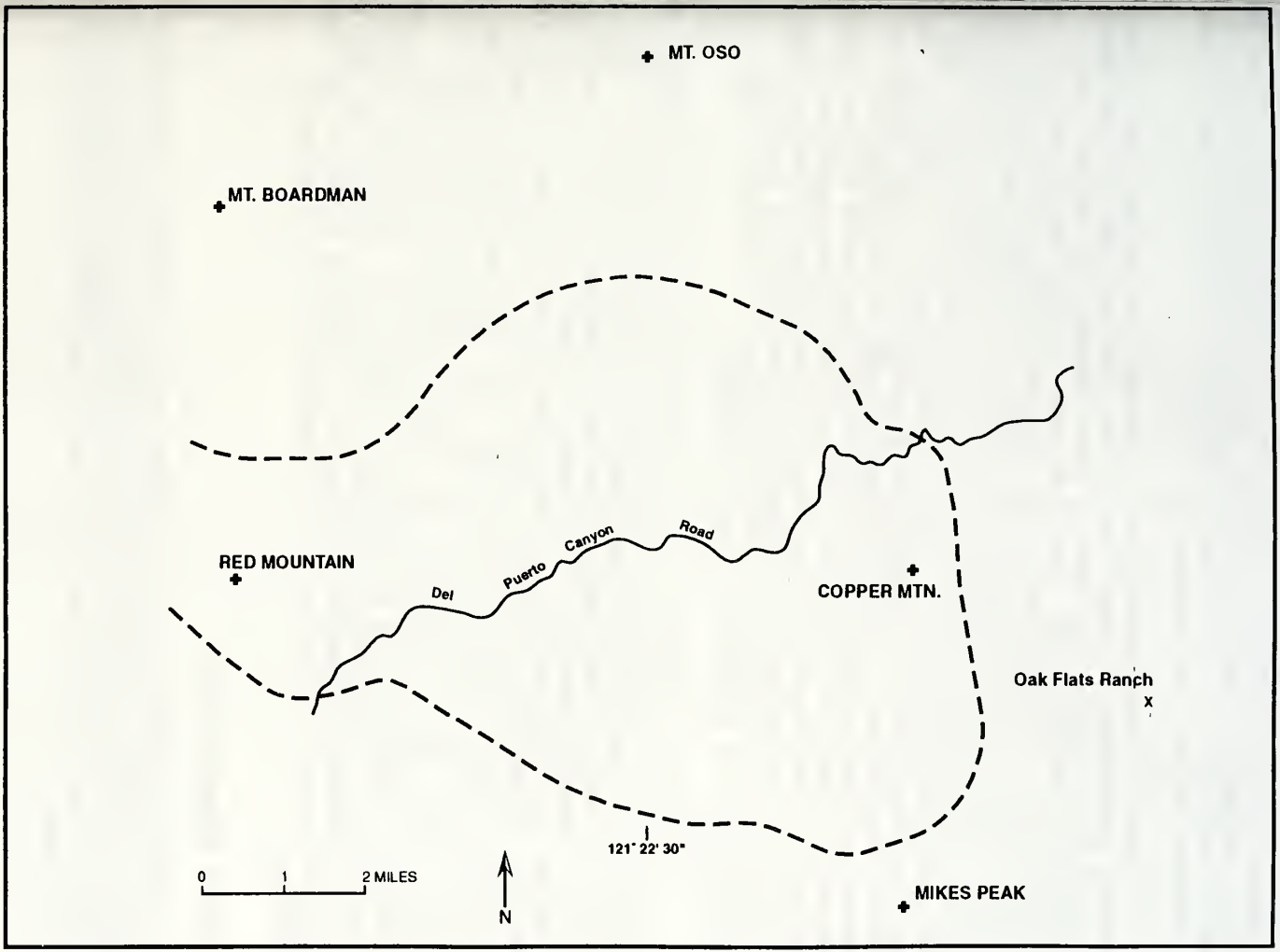


FIGURE C-1. – Outline of area associated with Red Mountain aeromagnetic anomaly that may have concealed bodies of serpentinite or ultramafic rock. Interpretation based on data from Plate 10.

centered southeast of Denair. The anomaly is characterized by a relatively steep gradient on the northeast side and a gentle gradient on the southwest side. On the northeast side, magnetic values decrease downward toward an associated negative anomaly. These magnetic anomalies and the associated gravity anomalies mentioned above are believed to represent oceanic crust in the basement (Zoback and Wentworth, 1986).

Plate 10 also shows a major change from broad, relatively smooth aeromagnetic anomalies in the central part of the Great Valley to a complex pattern of local anomalies, which trend generally northwest and have moderate-to-high amplitudes, in the eastern part of the county. The magnetic anomalies on the eastern edge of the county appear to be mainly associated with the Gopher Ridge Volcanics and possibly with other metamorphic or plutonic rocks. The change in the anomaly pattern is quite abrupt and it may mark the southwestern edge of the Jurassic island-arc terrane in the subsurface. The approximate location of this change is shown by a dashed line in Figure C-2. The broad negative anomalies that characterize much of the area west of the line shown in Figure C-2 are the counterparts of the positive anomalies that represent the Great Valley High, situated just to the west. One somewhat isolated positive magnetic anomaly centered near Waterford may be a fragment of oceanic crust believed to be present to the southwest.

Similar to observations by Henderson and others (1966), in general it is difficult to detect any consistent correlation between the magnetic pattern for the part of the area in the Sierran foothills and known base-metal (copper-zinc) deposits. Several nearby deposits in adjacent Calaveras County (Plate 8C) such as the Napoleon Mine, the Collier Mine, the Quail Hill Mine and the Gopher Hill Mine are all either on or close to small magnetic highs. Also, the Oat Hill Mine and the Mitchell Mine in Tuolumne County, farther southeast, are also on small magnetic highs. This is not true for all nearby deposits, however. Nonetheless, it is possible that the association between positive magnetic anomalies and base-metal deposits is frequent enough to suggest that such magnetic anomalies in areas covered by Tertiary and Quaternary sedimentary rocks are favorable areas to prospect for the copper-zinc ores that characterize this island-arc terrane.

Ground Magnetic Data

Ground magnetometer traverses were run with a Geometrics proton-precession magnetometer to determine on the ground the expressions of some of the aeromagnetic anomalies and whether there is any correlation with mineralized zones or particular rock types.

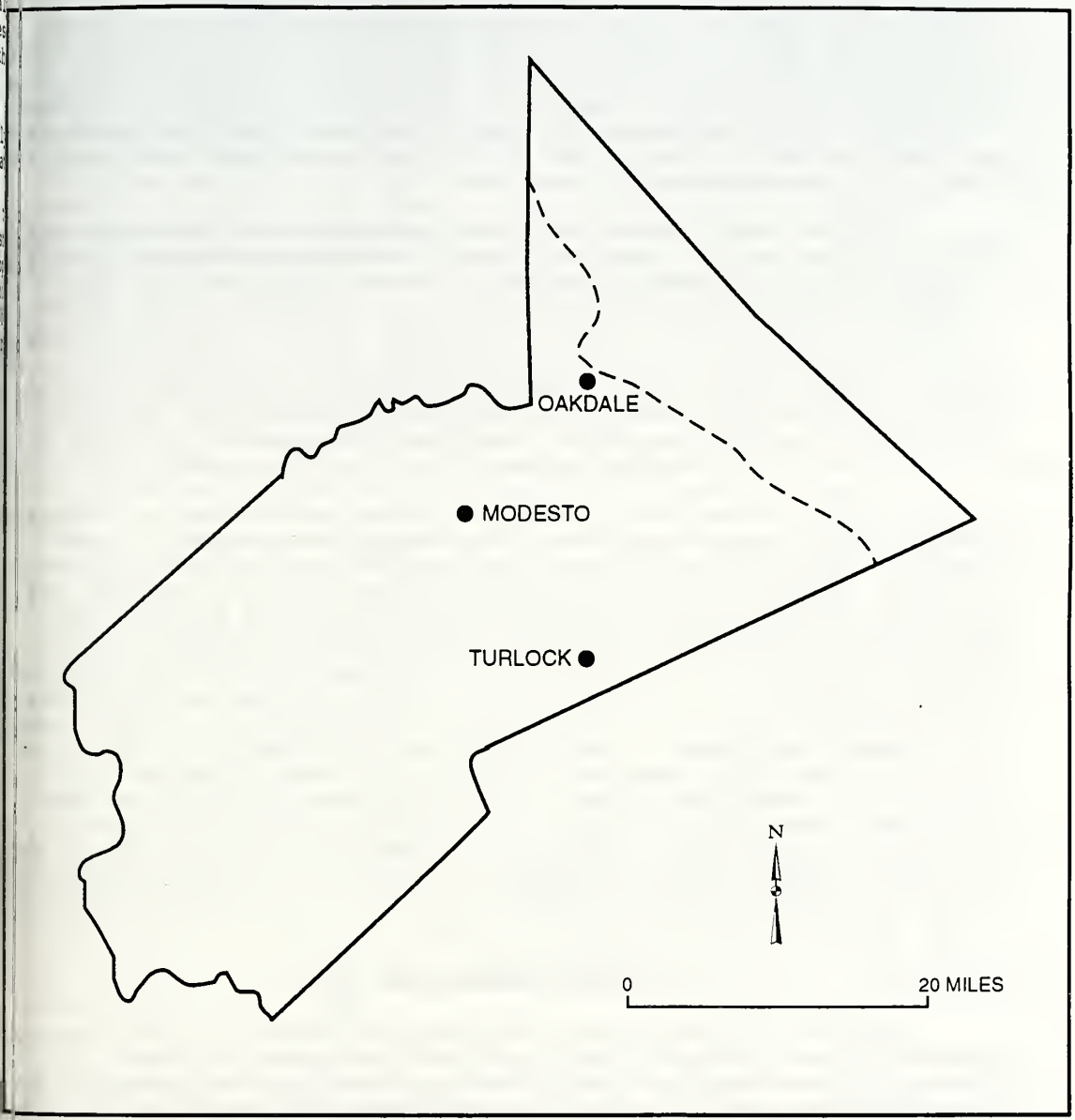


FIGURE C-2. – Approximate location (dashed line) of southwestern boundary of Jurassic island-arc terrane in subsurface, based on aeromagnetic data.

Profiles run along State Route 4 in Stanislaus and Calavera Counties (Chapman and others, in preparation) show irregular small anomalies over metavolcanic rocks and a zone of intrusive(?) felsic rock. A fairly strong positive anomaly is associated with a roadcut through a section of mixed metavolcani rocks in Sections 16 and 17, T1N, R11E. This anomaly corresponds to a northwest-trending positive aeromagnetic anomaly on Plate 10. There was no obvious correlation between possible mineralize zones observed on the ground, which may cross this area, and the magnetic anomalies on the profiles.

Several other ground magnetic profiles were obtained over small aeromagnetic anomalies along the eastern edge of Stanislau County where the depth of Cenozoic cover is believed to be relatively shallow (Chapman and others, in preparation). The anomalies were found to have amplitudes on the ground profiles o up to 1000 nanoteslas, but they are generally quite irregular as might be expected if they, as believed, represent metavolcanic rocks that have variable magnetic properties. There is no evidence that these magnetic anomalies necessarily have any association with possible mineralization in the area.

Attempts were made to use the aeromagnetic data to estimate depths to basement rocks for a few anomalies located in the eastern part of Stanislaus County using the slope and half-slope methods. In general, using profiles along flight lines was not very successful, probably because the contouring process has distorted the data somewhat. In some examples, however, the results appear to be reasonable. For example, an anomaly located north of Eugene in Section 26, T1N, R10E, yielded an elevation o the basement surface of about 1,500 feet below sea level in an area where the basement map by Bartow (1983) shows an elevation of 1,600 feet below sea level. Also, an anomaly located in Sections 17 and 18, T3S, R13E, about three miles north of the Tuolumne River, gives a depth below ground surface of about 2,30 feet. The exploration drill hole in Section 20, T3S, R13E, about two miles to the south, reached a depth of 2,600 feet, apparentl without reaching basement rocks.

SEISMIC REFRACTION DATA

Seismic refraction data (Chapman and others, in preparation were obtained over parts of the Orestimba Creek fan west of Newman to measure the seismic velocities of the fan material and to determine whether gravel horizons here could be distinguished by this means from sand or clay horizons. All of the lines trend north-south and were located along dirt roads and trails, generally along orchards. Available water well logs in this area were of little help for identifying the seismic layers because only a few logs were found in the immediate area, and those were difficult to interpret.

Profile 1 was located just south of Orestimba Creek and north of Stuhr Road, along the line between Sections 9 and 10. It consisted of three geophone-spread segments and was 825 feet long. The seismic data on this profile show a soil layer with a velocity of about 1000 feet per second (fps) that varies in thickness from 5 to 10 feet. Below the soil layer is a layer with a thickness of 35 to 50 feet having a velocity of 2500 to 2600 fps. This layer is believed to represent gravel of possible aggregate quality as this material is exposed in cuts along Orestimba Creek near the end of the seismic profile. Below the 2600 fps material, a layer with the highest velocity found on the profile (3800 to 4600 fps) is present. There is no direct evidence for what this velocity represents, but it may be older, more consolidated gravel. This velocity is not fast enough to represent the water table. No layers were detected below this, so there is no indication of how thick this material might be.

Profile 2 was located south of Stuhr Road along the line between Sections 15 and 16 and was 2,475 feet in length. On this profile, the soil layer ranges in thickness up to about 10 feet. Underlying this layer throughout the length of the profile is a layer having a velocity that ranges between 2500 and 3000 fps and a thickness of from 30 to 60 feet. This layer may be a continuation of the similar layer found on Profile 1, just to the north. In the northern portion of this profile (as far south as station 1100) there is also an intermediate layer with a velocity of between 2000 and 2200 fps and a thickness of up to 15 feet. The material that causes this velocity is not known, but it may be a layer composed mostly of sand. As in Profile 1, the lowest layer that could be detected has a velocity of from about 3700 to 4000 fps.

Profile 3 was located just north of Orestimba Creek along the line between Sections 9 and 10 and was 1,100 feet long. On this profile, the soil layer is up to 8 feet thick; it is underlain by a layer with a velocity of from 2200 to 2500 fps and a thickness of from 30 to 60 feet. This velocity is distinctly lower than the one found on the profiles just south of Orestimba Creek (Profiles 1 and 2). Although we do not have enough information to know why there is a difference, it may be that there is more sand or clay mixed with the gravel in this area. As on Profiles 1 and 2, the lowest layer detected has a velocity of from 3600 to 4400 fps.

Profile 4 extended from near the center of Section 16 south to the Orestimba Creek Road and was 2,475 feet in length. On this profile, the soil layer was found to be very thin, not exceeding 3 feet in thickness. Below the soil layer is a layer with a very uniform velocity of 2800 to 2900 fps. It ranges in thickness from about 15 feet at the extreme south end of the profile to 70 feet or more at the north end. Although the velocity is similar to that for the gravel of probable aggregate quality on Profile 1, without an actual examination of the material it is difficult to know whether it is the same or different. On this profile, there

is no 3600-4400 fps layer, but from about the center of the profile to the south end, there is a layer with a velocity of from about 6900 to 7600 fps. This is the highest velocity layer found in the area. It appears to gradually rise toward the surface as the south end of the profile is approached. It may represent more-consolidated older Quaternary alluvium, which is exposed in the area just south and west of the south end of the profile. There is no positive evidence for the location of the San Joaquin Fault on the profile except for a possible disturbed area located near the north end between stations 275 and 825, but this may have other causes.

Profile 5 was located in the northern part of Section 9 and was 1,375 feet in length. This profile appears to be somewhat north of the main Orestimba Creek fan. For this reason, it was somewhat unexpected to find below the soil layer a layer with a velocity of about 2600-2900 fps, which is very similar to most of the other profiles. Whether the material that represents this velocity is good aggregate is not known. The 3600-4400 fps layer was not found on this profile, except possibly in one area, where it may be at a depth of about 60 feet. Therefore, this layer may be present, but is somewhat too deep to detect on most of the profiles.

CONCLUSIONS

New gravity data obtained in Stanislaus County and vicinity have provided additional detail on the major regional gravity features in the area and also have delineated some relatively local anomalies. The major anomalies include a negative anomaly associated with the synclinal structure underlying the San Joaquin valley with an axis near the western side, and a positive anomaly, the "Great Valley high", centered somewhat east of the center of the valley, that is believed to represent a zone of oceanic crust in the pre-Tertiary basement. Also included are a negative anomaly located northeast of Oakdale that may represent a granitic intrusion in the basement rocks, and a negative anomaly in the Coast Ranges that may correspond with a positive aeromagnetic anomaly over serpentinite and other ophiolitic rocks.

Of particular interest in this study are local gravity anomalies on the southwestern and northeastern margins of the Great Valley. In the Cooperstown-La Grange area, a west-trending negative anomaly may represent an ancient channel of the Tuolumne River. A possible tributary to this channel may trend for some distance north of the Tuolumne River anomaly toward Cooperstown. If this possible valley existed at the time the Ione Formation was being deposited, relatively thick deposits of this formation, including possible valuable clay and lignite deposits, might be found within this feature. Available drill-hole logs in this area indicate that this buried topographic feature, if present, does not extend as far north as the immediate Cooperstown area. On the

southwestern edge of the valley, a small gravity anomaly, possibly associated with the San Joaquin Fault, was found on a profile in the vicinity of Salado Creek. There was no apparent anomaly found on a profile along Orestimba Creek, however.

The part of the Great Valley negative gravity anomaly within the -60 Mgal contour west of Newman defines an area characterized by a number of thick deposits of low-density diatomite. This part of the anomaly may indicate the presence of undiscovered deposits of diatomite in areas where they are not exposed.

In general, aeromagnetic data show anomalies that correspond to serpentinite and other ultramafic rocks in the Coast Ranges and in the Great Valley. They also show a characteristic pattern of northwest-trending anomalies associated with the Jurassic metavolcanic rocks in the foothills on the northeastern side of the county. The boundary between these northwest-trending anomalies and a relatively smooth pattern of anomalies in the northeastern part of the Great Valley may mark the southwestern edge of Jurassic island-arc terrane in the basement.

In the Coast Ranges, the magnetic anomalies indicate that the ultramafic rocks are more extensive than is apparent on the surface and, therefore, that there may be undiscovered deposits of chromite and magnesite present in these areas. Detailed magnetic surveys would be required to delineate local anomalies that may be associated with these types of rocks.

In the Sierra Nevada foothills, on the northeastern side of the county and in the adjoining counties, there is a possible, though somewhat weak, correlation between positive aeromagnetic anomalies and known copper-zinc deposits. This possible correlation suggests that the positive magnetic anomalies in the area might be the most favorable locations for exploration for such undiscovered deposits. Ground magnetic data suggest, however, that most of the aeromagnetic anomalies are caused by relatively magnetic metavolcanic rock units and are not associated directly with mineral deposits.

Seismic refraction profiles in the Orestimba Creek fan area show velocities that range from about 1000 feet per second (fps) for near-surface soil to a maximum of about 7600 fps for possible consolidated alluvium. The velocity of a layer of probable aggregate-quality gravel on one line was found to be in the range of 2500 fps to 2600 fps. Layers with velocities in the 2500-3000 fps range were found on most of the other seismic profiles. Layers with distinctly lower velocities found on some of the profiles are believed to be mostly sand or sandy alluvium. In contrast, higher velocities may represent a relatively consolidated alluvium. Because of the lack of subsurface samples

in the area, it is not known if the 2500-3000 fps seismic velocity is characteristic of aggregate-quality gravel, or even if there is any well-defined relationship between seismic velocity and quality of gravel. The seismic velocity data do, however, suggest areas that could be tested to determine if aggregate deposits of possible commercial interest are present.

APPENDIX D

Photographs

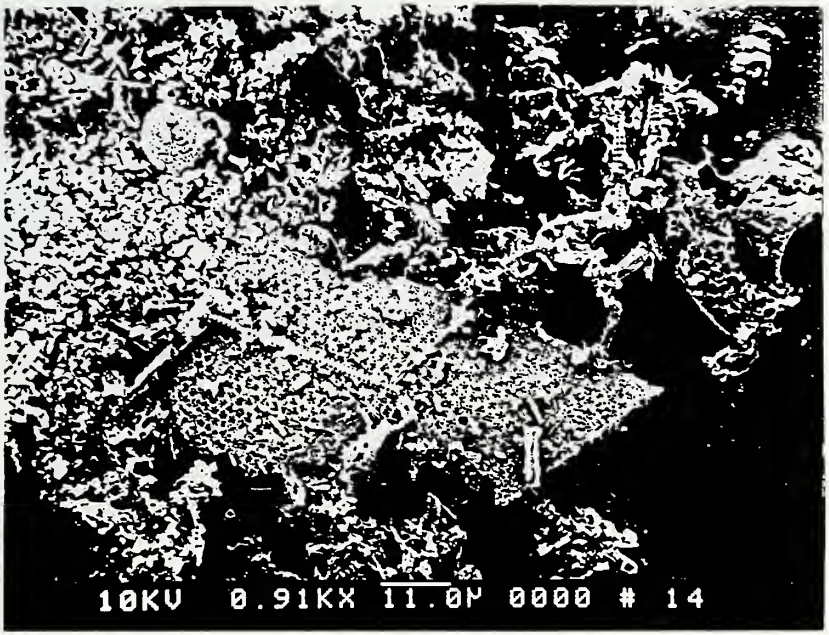


PHOTO 1. – Diatomite of Kreyenhagen Shale from near Crow Hill (sample STC-14a). Photo taken with scanning electron microscope at a magnification of 910X.

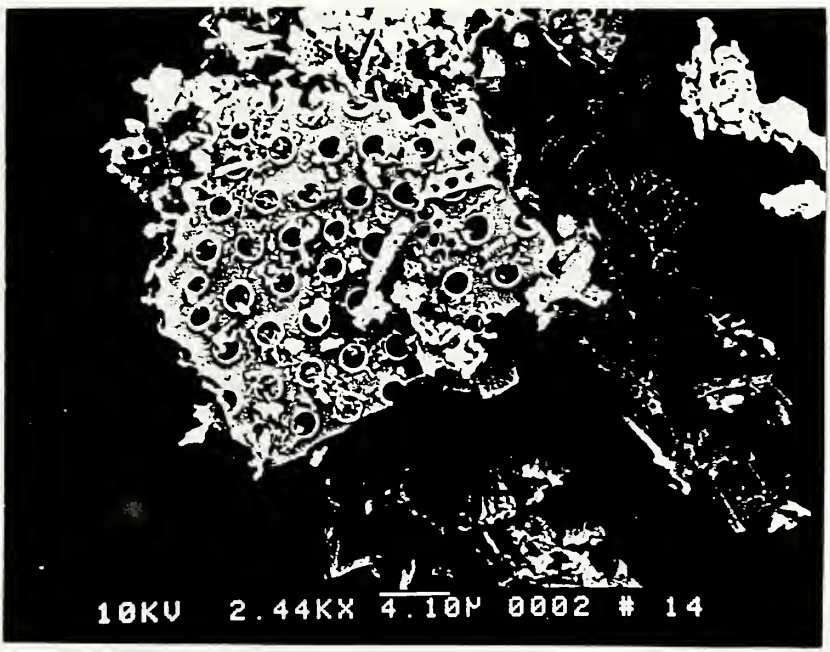


PHOTO 2. – Diatomite of Kreyenhagen Shale form near Crow Hill (sample STC-14a). Photo taken with scanning electron microscope at a magnification of 2,440X.

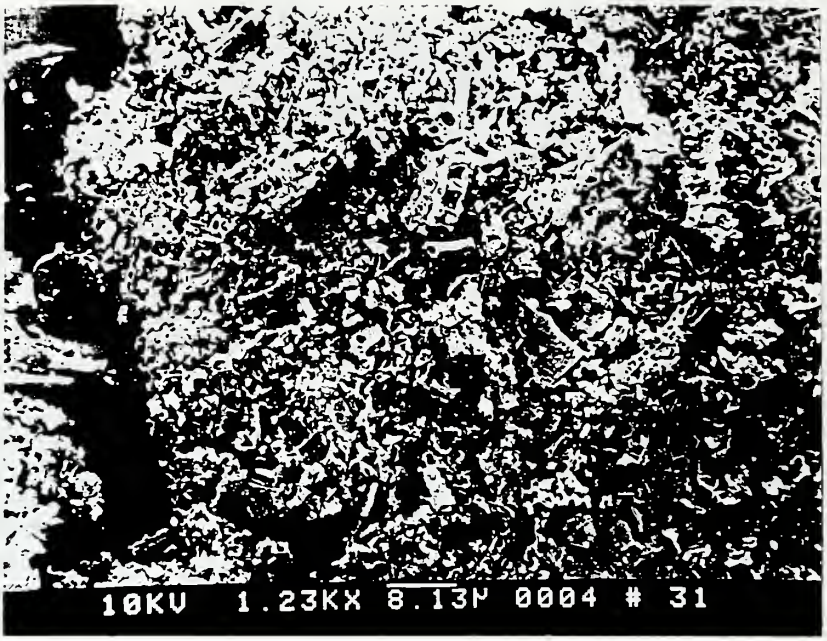


PHOTO 3. – Diatomite of Kreyenhagen Shale from near Crow Hill (sample STC-31). Photo taken with scanning electron microscope at a magnification of 1,230X.

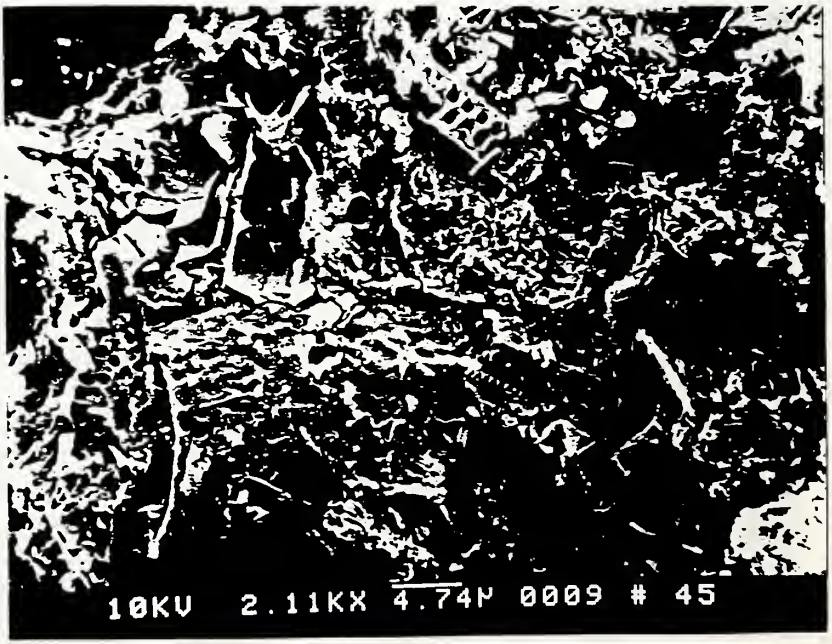


PHOTO 4. – Diatomite of Kreyenhagen Shale from near Crow Hill (sample STC-45a). Photo taken with scanning electron microscope at a magnification of 2,110X.

PHOTO 5. – Dredge of Tuolumne Gold Dredging Company in operation a few miles south of La Grange during the 1940s. Photo taken from Charles (1947).

PHOTO 6. – Same dredge as in Photo 5, taken in 1992. The dredge is in an undeveloped county park, just south of Dawson Lake near La Grange.

PHOTO 7. – North workings of Buckeye Mine in southwestern Stanislaus County in 1943. Manganese was mined from the prominent chert beds visible on the slopes. Photo taken from Jenkins and others (1943).

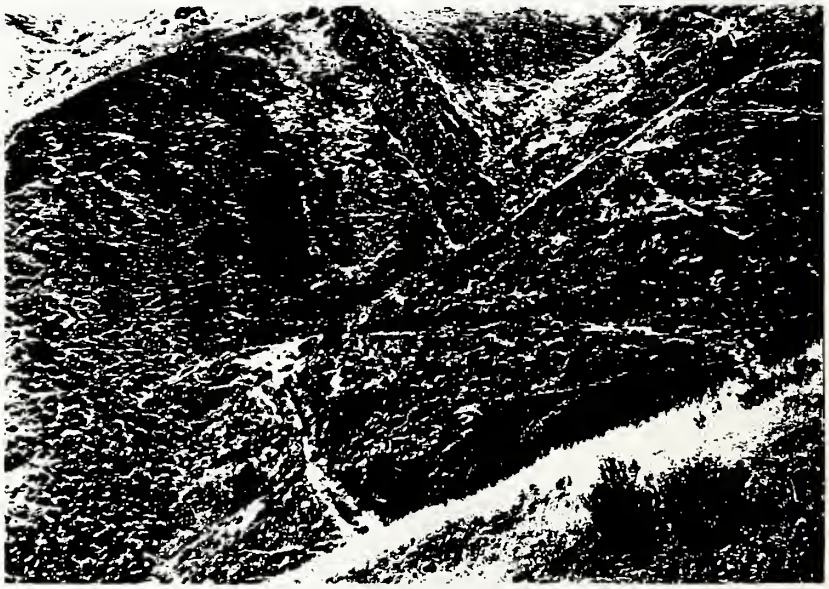


PHOTO 8. – Similar view of Buckeye Mine, taken in 1993. Main ore body was first mined from an open cut visible in the very upper right corner of the photo.

HOTO 9. – The Division of Mines and Geology's geophysical team conducting a seismic refraction survey
ross the Orestimba Creek Fan. A 300-pound weight is being dropped onto a steel strike plate. Seismic
ock waves that emanate from the weight's impact refract off subsurface strata and are transmitted to
ophone sensors place in the ground. Electronic signals are then transmitted by the geophones to the
ismograph located at the rear of the vehicle in the background, and interpreted by a geophysicist (Photo
). Shallow seismic refraction and electrical-resistivity surveys are increasingly being used to quickly gather
bsurface geologic information in the exploration for aggregate resources.

PHOTO 10. – Geophysicist operating a seismograph used in the Orestimba Creek Fan seismic refractio survey. He will later interpret the seismogram readings to determine the depth and thicknesses of subsu sand, gravel and clay deposits.

PHOTO 11. – View of the Coast Ranges to the west from the San Joaquin Valley showing the faceted lobate onfiguration (right center) of an elevated Pliocene alluvial fan about one mile south of Del Puerto Canyon. nterstate Highway 5 is perpendicular to the fan and cuts its toe. Although several Coast Ranges alluvial fans imilar to this one contain massive tonnages of sand and gravel, the quality of the sediments within them is nuch less than that of the aggregate within Stanislaus and Tuolumne river channel deposits in eastern Stanislaus County.

PHOTO 12. – View of the mouth of Del Puerto Canyon. A resistant well-cemented Tertiary conglomerate forms the narrow outlet in the center where Del Puerto Creek cuts through. Del Puerto Canyon Road follo Del Puerto Canyon westward to the crest of the Coast Ranges. This road provides a convenient way to v the varied rock formations that form the rugged topography of the Coast Ranges in western Stanislaus County.

HOTO 13. – Carbonate coatings, or "skins", on cobbles within Del Puerto Fan. These coatings are common, especially in the deeper and older fanglomerate beds within the eastern Coast Ranges fans of Stanislaus County. Because such carbonate coatings have the potential of reacting with portland cement when used in concrete. It is important that engineering tests be performed prior to mining to determine aggregate quality.

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA · PETE WILSON, GOVERNOR
THE RESOURCES AGENCY · DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION · EDWARD G. HEIDIG, DIRECTOR

GEOLOGIC MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

by
Chris T. Higgins and Laurel S. Jensen

1993

Note: The geologic compilation (Plates 1A, 1B, and 1C) was made for the purpose of a mineral resource investigation and is not suitable for application to investigations of geologic hazards involving slope stability, ground stability, surface fault rupture, or other types of geologic hazards. Such investigations should rely on appropriate published reports or on original investigations conducted at appropriate levels of detail and scale.

SYMBOLS

- Geologic contact
- Fault, dashed where approximate, dotted where concealed; U - up, D - down
- Strike and dip of bedding
- Axis of anticline
- Axis of syncline
- Area of gravel mapped by USDA Soil Conservation Service (unpublished)
- County Line

SCALE 1:48,000

1 0 1 2 3 Miles

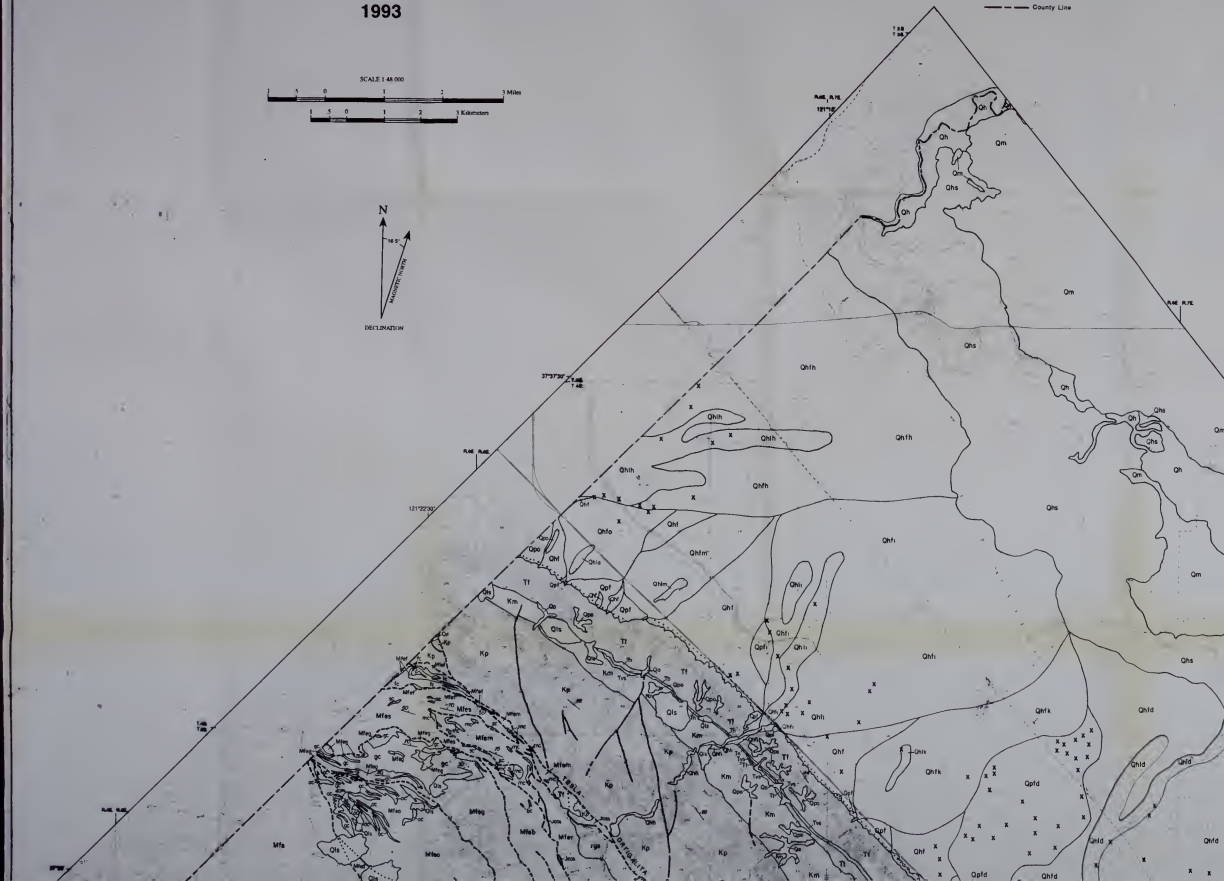
1 5 0 1 2 3 Kilometers

N

16.5°

MAGNETIC NORTH

DECLINATION


T 3S
T 4S
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37°37'30"
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Qh
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Mfsa
Mfsi
Mfsj
Mfsk
Mfsu
Mfst
Mfso

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DEPARTMENT OF CONSERVATION · EDWARD G. HEIDIG, DIRECTOR

N24
S
R33
no. 173
PLATE 1A
Phys
Sci Lib

SYMBOLS

Geologic contact

Fault, dashed where approximate, dotted where concealed
U - up, D - down

40 Strike and dip of bedding

Axis of anticline

Axis of syncline

X Area of gravel mapped by USDA Soil Conservation Service (unpublished)

County Line

Note: The geologic compilation (Plates 1A, 1B, and 1C) was made for the purpose of a mineral resource investigation and is not suitable for application to investigations of geologic hazards involving slope stability, ground stability, surface fault rupture, or other types of geologic hazards. Such investigations should rely on appropriate published reports or on original investigations conducted at appropriate levels of detail and scale

GEOLOGIC LEGEND

QUATERNARY — HOLOCENE

- Qh — Post-Modesto alluvium: alluvial sand, silt, gravel and clay along the Tuolumne and Stanislaus Rivers. Dominantly arkosic
- Qhs — Post-Modesto alluvium, alluvial sand, silt and clay along the San Joaquin River channel and flood basin. Derived from both the Sierra Nevada and Coast Ranges
- Qhs — Post-Modesto active sand; associated with modern dunes

The following Quaternary units are adapted from Helley and others (unpublished) and Bowers and others (unpublished). All Holocene units are equivalent in age

- Qhh — Hospital Creek
- Qha — Arbuckle Creek
- Qhm — Martin Creek
- Qhi — Ingram Creek
- Qhk — Kern Creek
- Qhd — Del Puerto Creek
- Qhs — Salado Creek
- Qhc — Crow Creek
- Qhe — Orestimba Creek

Unconsolidated sand, silt, and gravel associated with stream channels and terraces along the west side of the San Joaquin Valley and east flank of the Coast Ranges. Units are differentiated by the creek that deposited them, all of which originated in the Coast Ranges. They are listed from north to south

- Qhh — Hospital Creek
- Qha — Arbuckle Creek
- Qhm — Martin Creek
- Qhi — Ingram Creek
- Qhk — Kern Creek
- Qhd — Del Puerto Creek
- Qhs — Salado Creek
- Qhc — Crow Creek
- Qhe — Orestimba Creek
- Qhg — Garzen Creek

Unconsolidated deposits of sand, silt, gravel and clay associated with alluvial fans and terraces along the west side of the San Joaquin Valley and east flank of the Coast Ranges. Units are differentiated by the creek that deposited them, each of which originated in the Coast Ranges

- Qhb — Black Gulch
- Qhl — Little Salado Creek

- Qhf — Undifferentiated deposits of sand, silt, gravel and clay associated with channels, terraces, alluvial fans and terraces along the west side of the San Joaquin Valley and east flank of the Coast Ranges. The deposits were formed by small creeks with very limited areas of drainage in the Coast Ranges

QUATERNARY — HOLOCENE AND PLEISTOCENE

- Qa — Alluvium, undifferentiated (generally Holocene or younger Pleistocene channel and terrace deposits)
- Qls — Landslide
- Qm — Modesto Formation, alluvial sand, silt, gravel and clay associated with fans, channels and terraces. Dominantly arkosic. Includes undifferentiated eolian sand

Unconsolidated younger Pleistocene deposits of sand, silt, gravel and clay associated with channels, terraces, alluvial fans and terraces along the west side of the San Joaquin Valley and east flank of the Coast Ranges. Units are differentiated by the creek that deposited them. They are listed from north to south

- Qph — Del Puerto Creek
- Qpl — Little Salado Creek
- Qpb — Orestimba Creek

- Qpf — Undifferentiated younger Pleistocene deposits of sand, silt, gravel and clay associated with channels, terraces, alluvial fans and terraces along the west side of the San Joaquin Valley and east flank of the Coast Ranges. These deposits were formed by small creeks with very limited drainages in the Coast Ranges

- Qyn — Undifferentiated older Pleistocene-quaternary sand, silt, gravel and clay associated with alluvial fans terraces and pedimonts along the west side of the San Joaquin Valley and east flanks of the Coast Ranges. These deposits range from unconsolidated to consolidated weakly cemented sediments

TERTIARY — PLIOCENE

- Tl — Fanglomerate: conglomerate, sandstone, and siltstone
- Tv — Volcanic dikes: intermediate composition porphyritic, hydrothermally altered in places

TERTIARY — MIOCENE

- Tc — Neroly Sandstone: nonmarine andesitic sandstone
- Tvs — Valley Springs Formation: clayey sandstone, sandy tuffaceous claystone, and vitric tuff

TERTIARY — OLIGOCENE

- Tpf — Poverty Flat Sandstone: dominantly sandstone with minor interbedded claystone and siltstone. Contains a thick sequence of quartz-lapidus sandstone in upper part

TERTIARY — EOCENE

- Tk — Kreyenhagen Shale: shale, diatomaceous shale and diatomite with minor sandstone in lower part. Clastic dikes of sandstone are common
- Td — Domengine Sandstone: well-indurated glauconitic quartz sandstone

TERTIARY — PALEOCENE

- Tt — Tesla Formation, fine-grained sandstone and siltstone
- Ttg — Tesla Formation, quartz sandstone members

GREAT VALLEY SEQUENCE

CRETACEOUS

- Kvs — Moreno Formation, interbedded marine shale and sandstone with shale dominant. Deposited by turbidity currents
- Kp — Panoche Formation: interbedded marine sandstone and siltstone with lenses of conglomerate in lower part of unit. Includes Adobe Flat Shale Member in Wilson Ridge area. Deposited by turbidity currents

JURASSIC — CRETACEOUS

- JKaf — Panoche Formation (Adobe Flat Shale Member), marine silty shale, siltstone, and sandstone (includes Kreyenhagen?) Formation as mapped by Maddock (1964)
- Jtt — Little Creek Tuff: interbedded volcaniclastic lithicite sandstones and thin-bedded tuffaceous chert

COAST RANGE OPHIOLITE

The following units are adapted from Cowie (1974)

- Jmv — Volcanic Member: extrusives and shallow intrusives submarine volcanic rocks of mafic to silicic composition (metamorphosed to spilite and keratophyre)
- Jgp — Plutonic Member: granodiorite cumulates grading upward into gabbro cumulates and quartz diorites. Entire member cut by small intrusions of diabase, microdiorite, and plagiogranite
- Jsd — Alpine Peridotite Member: dunite-wehrlite unit; cumulate-textured dunite with minor wehrlite variably serpentinized. Contains podiform and disseminated chromite
- Jsah — Alpine Peridotite Member: harzburgite unit (includes antigorite-schist and minor serpentinite) partially serpentinized, massive. Formed beneath upper which remainder of ophiolite was emplaced
- Jsd — Dunite pods in harzburgite unit; irregular to tabular bodies, distinct in composition from the dunite wehrlite unit
- Jsm — Serpentinite: undifferentiated (may be part of Coast Range Ophiolite or melange of Franciscan Complex); generally sheared with some remnants of ultramafic protolith

FRANCISCAN COMPLEX

The Franciscan Complex is subdivided here into two lithostratigraphic terranes of metamorphosed marine sedimentary and igneous rocks, the younger Burro Hills and the older Eylar Mountain, which are adapted from Blake and others (1990) and Bennison and others (1989)

Burro Hills Terrane

- Mbs — Burro Hills Terrane: undifferentiated: massive to thin-bedded metagraywacke and lithophilic sandstone with minor siltstone, chert, and greenstone. Composition of sandstone suggests a predominantly granitic source

Eylar Mountain Terrane

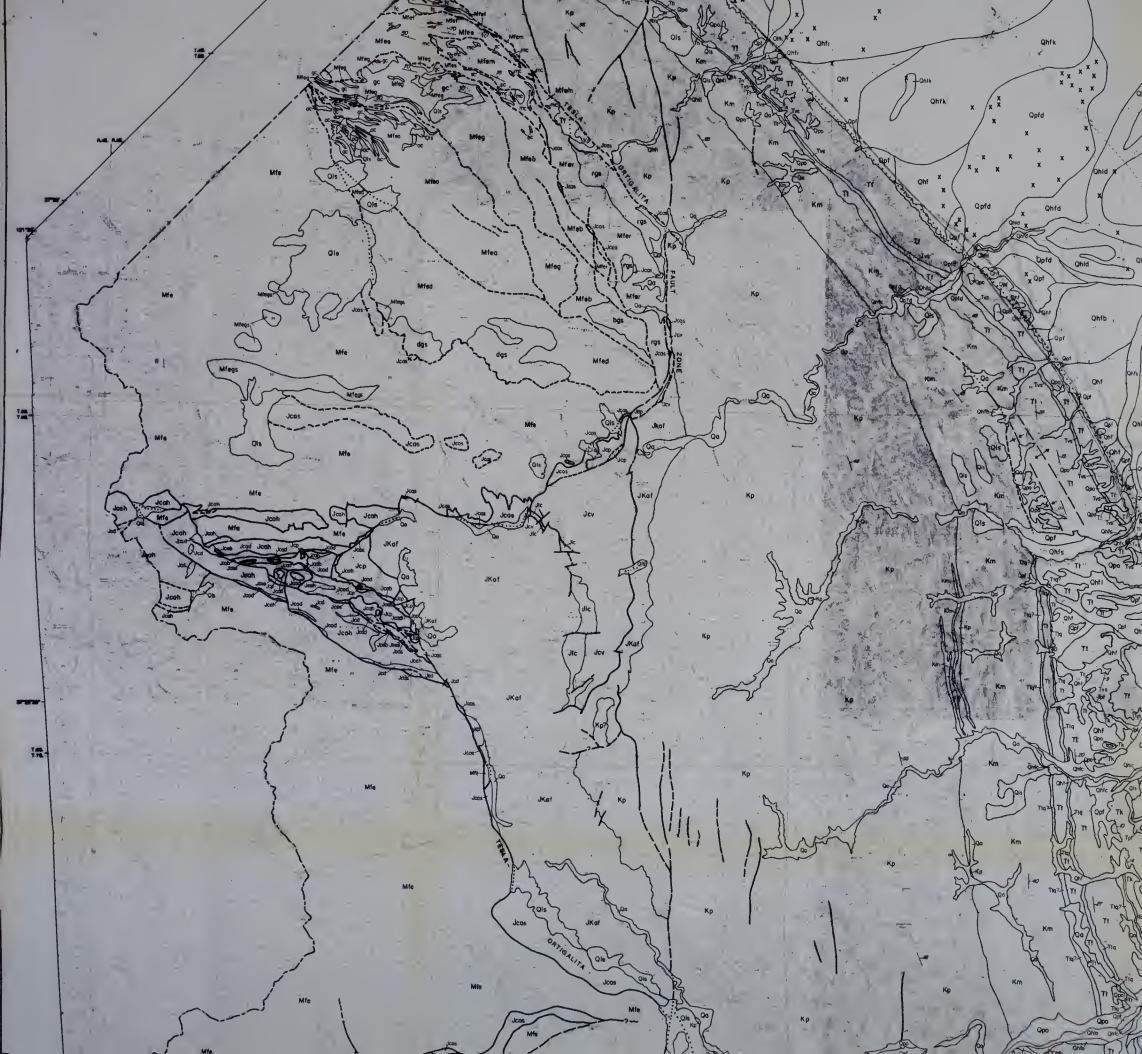
- Mfe — Eylar Mountain Terrane: undifferentiated (may include some Burro Hills Terrane or Mt. Stakes terrane): zones of coherent sedimentary-matured strata interbedded with melange. Most of this unit may be melange, which consists mainly of tectonic blocks of graywacke, chert, greenstone (glaucophane schist), and serpentinite in a sheared mudstone matrix. Coherent sequences consist dominantly of metagraywacke and siltstone-shale with lesser amounts of chert and greenstone
- Mmgs — Mountainous, undifferentiated submarine basaltic lavas subsequently metamorphosed (Maddock, 1964)

The following units are adapted from Raymond (1973), Maddock (1964) and Tiedt and others (1960)

- Mbd — Bird Man's Broken Formation: 52% metagraywacke-metashale-metasiltstone; 28% metaigneous; 20% metachert-metashale
- bc — Chert (most abundant in north)
- bgn — Greenstone (most abundant in south)
- Mdd — Douglass Melange: 45% metagraywacke-metashale-metasiltstone; 30% metagreenstone; 25% metachert-metashale
- dgn — Greenstone
- Mfsf — Folsom Formation: 70% metachert-metashale (thin-bedded); 25% metagraywacke-metashale-metaconglomerate; 5% metachert (thick-bedded)
- fc — Chert
- Mmg — Grunhurst Broken Formation: 80% metachert-metashale; 19% metagraywacke-metashale metasiltstone; 1% metaconglomerate
- gc — Chert
- Mfsm — Folsom Formation (Morrer Zone); 70% metagraywacke-metashale-metaconglomerate; 20% metachert-metashale
- mc — Chert
- Mbsc — Coe Broken Formation: 80% metagraywacke-metashale-metasiltstone; 18% metachert-metashale; 2% metagreen metaconglomerate
- cc — Chert
- Mbr — Rocky Point Melange: 25% metavolcanic; 20% metagraywacke-metashale-metasiltstone; 20% metachert-metashale; 15% serpentinite; 5% glaucophane schist-gneiss; 30% sheared matrix
- gn — Greenstone
- Mbh — Sulfur Gulch Broken Formation: 68% metagraywacke-metashale-metasiltstone; 4% metachert-metashale
- sc — Chert
- Mbcz — Emilio Melange/mixed: slab of coherent graywacke overlying melange of the undifferentiated Eylar Mountain Terrane (Cowan 1974)

JURASSIC-CRETACEOUS

T 9S R 5E
T 10S R 5E
R 4E R 5E
R 3E R 4E
T 9S R 6E
T 10S R 6E
121°15'
121°22'30"


Mfe
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Tfsp
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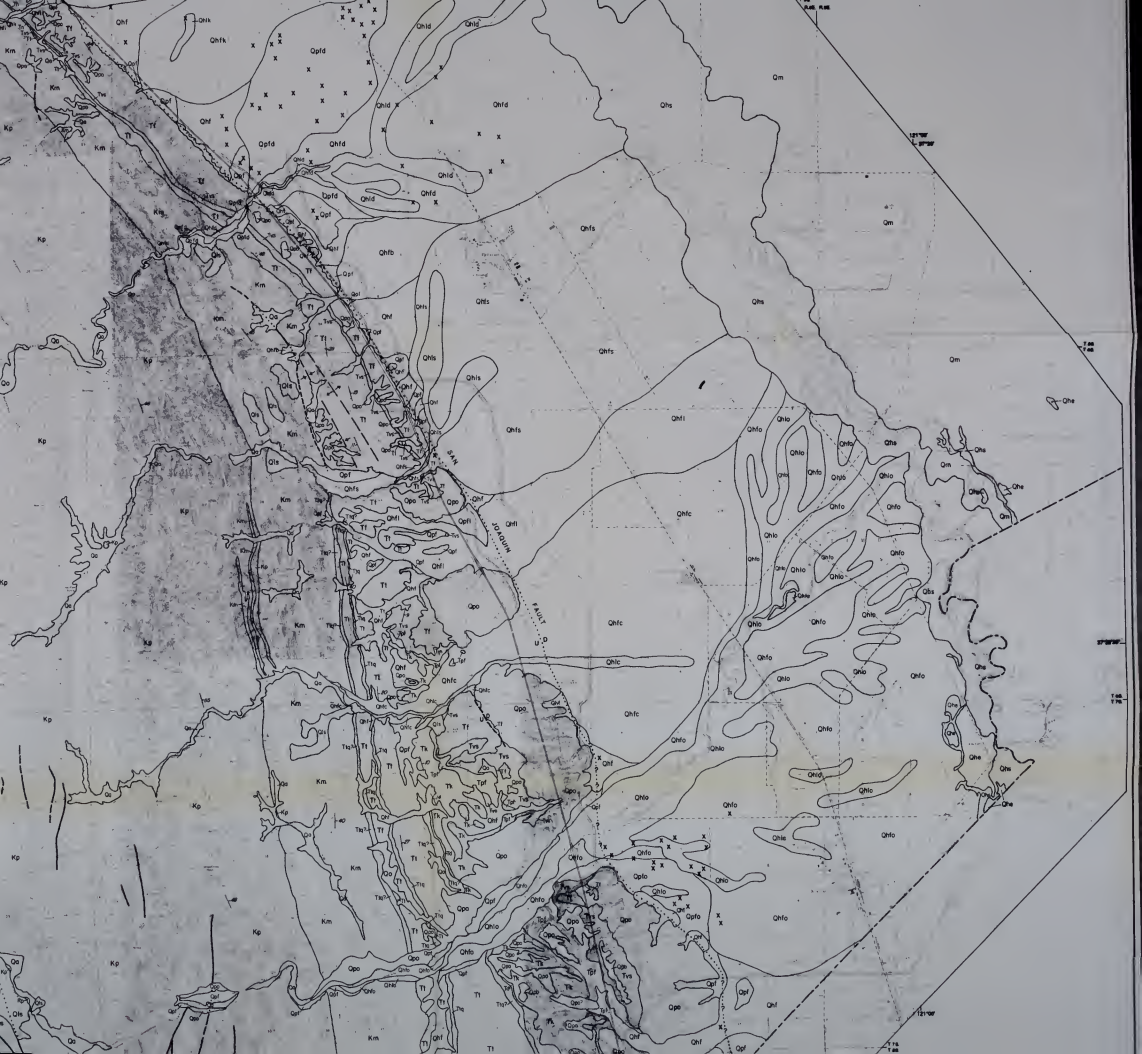
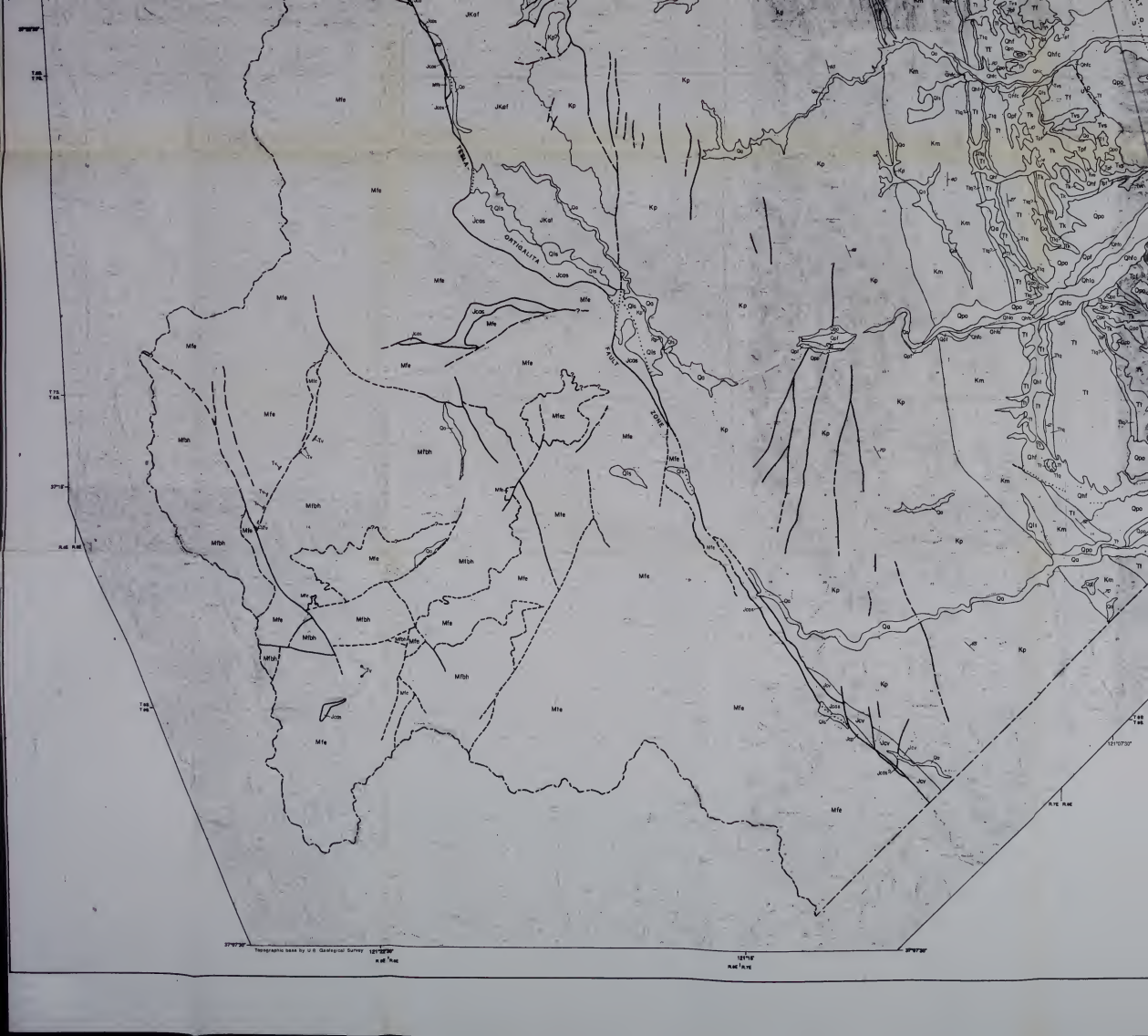
Tfsz
TERRA OATISALITA FAULT ZONE
TERRA OATISALITA


SAN
JACINTO
FAULT
ZONE


ORTIGALITA FAULT ZONE
Topographic base by U.S. Geological Survey

Index to U.S.G.S. 7.5-minute quadrangles and references used for compilation

REFERENCES FOR GEOLOGIC COMPILATION

1 Barlow and others (1985)
2 Booth (1950)
3 Cole and others (1948)
4 Collins (1949)
5 Dalton (1972)
6 Cowan (1974)
7 Dibblee (1975)
8 Dibblee (1981a)
9 Dibblee (1981b)
10 Dibblee (1982a)
11 Dibblee (1982b)
12 Dibblee (1982c)
13 Dibblee (1982d)
14 Everts (1978)
15 Lettis (1982)
16 Maddock (1964)
17 McLaughlin and Huntington (1968)
18 Morrell (1978)
19 Noller (unpublished)
20 Noller and others (unpublished)
21 Raymond (1973a)
22 Sowers and others (unpublished)
23 Trask and others (1950)
24 USDA Soil Conservation Service (unpublished)

Drafting and layout by J.A. Sullivan and E.L. Foster

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A33
no. 173
Plate 1B
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SPECIAL REPORT 173
PLATE 1B
GEOLOGY CENTRAL

GEOLOGIC MAP OF CENTRAL STANISLAUS COUNTY, CALIFORNIA

by
Chris T. Higgins and Laurel S. Jensen

1993

GEOLOGIC LEGEND

QUATERNARY

HOLOCENE

- Qh — Post-Modesto alluvium, alluvial sand, silt, gravel and clay along the Tuolumne and Stanislaus Rivers and Dry Creek. Dominantly arkosic
- Qhs — Post-Modesto alluvium, alluvial sand, silt, and clay along the San Joaquin River channel and flood basin. Derived from both the Sierra Nevada and Coast Ranges
- Qhe — Post-Modesto eolian sand; associated with modern dunes

PLEISTOCENE

- Qm — Modesto Formation, alluvial sand, silt, gravel and clay associated with fans, channels, and terraces. Dominantly arkosic. Includes undifferentiated eolian sand
- Qr — Riverbank Formation, alluvial sand, silt, gravel and clay associated with fans and terraces. Arkosic
- Qtl — Turlock Lake Formation, alluvial sand, gravel, silt, and clay associated with fans. Arkosic

SYMBOLS

- Geologic contact
- County line

SCALE 1:48,000

1 .5 0 1 2 3 Miles

1 .5 0 1 2 3 Kilometers

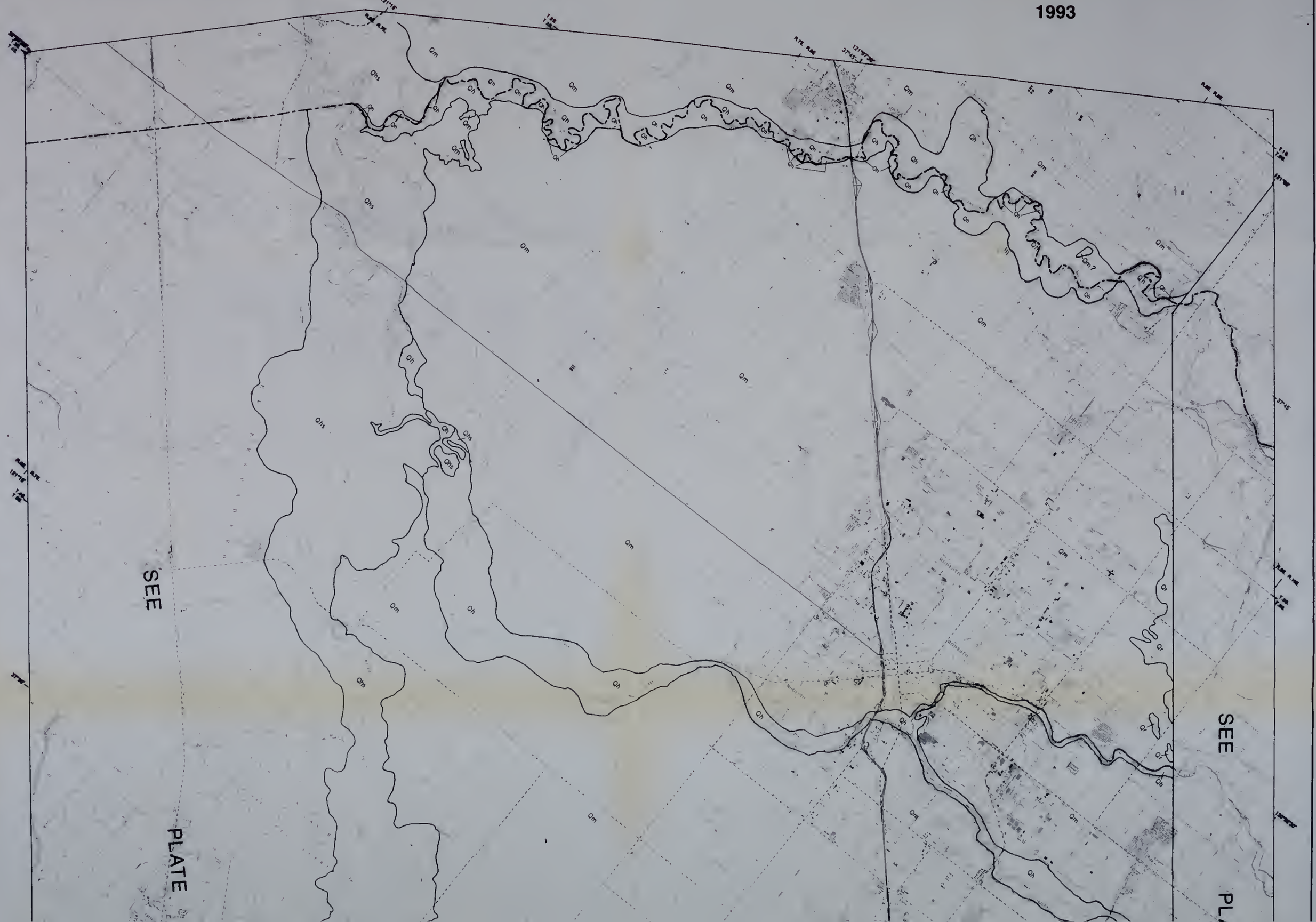


PLATE 1A

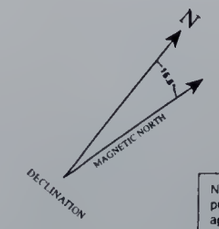
PLATE 1C

Topographic base by U.S. Geological Survey

Index map of U.S.G.S. 7.5-minute quadrangles and references used for compilation

REFERENCES FOR GEOLOGIC COMPILATION

1. Arkley (1964)
2. Cole and others (1948)
3. Lettis (1982)
4. Marchand (1976)
5. Marchand (1980)
6. Marchand and Harden (1978)
7. McLaughlin and Huntington (1968)
8. Retzer and others (1951)
9. USDA, Soil Conservation Service (unpublished)



Note: The geologic compilation (Plates 1A, 1B, and 1C) was made for the purpose of a **mineral resource investigation** and is not suitable for application to investigations of geologic hazards involving slope stability, ground stability, surface fault rupture, or other types of geologic hazards. Such investigations should rely on appropriate published reports or on original investigations conducted at appropriate levels of detail and scale.

Drafting and layout by Joy A. Sullivan

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Plate 1C
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SPECIAL REPORT 173
PLATE 1C
GEOLOGY NE

GEOLOGIC MAP OF NORTHEASTERN STANISLAUS COUNTY, CALIFORNIA

by

Chris T. Higgins and Laurel S. Jensen

1993

GEOLOGIC LEGEND

QUATERNARY

HOLOCENE

- t — Tailings: gravelly debris from placer mining
- Ql — Dry lake bed: silt
- Qh — Post Modesto alluvium: sand, gravel, and silt along the Tuolumne and Stanislaus Rivers and local creeks. Dominantly arkosic with some locally derived material

PLEISTOCENE

- Qm — Modesto Formation: alluvial sand, gravel, silt, and clay associated with terraces and fans. Dominantly arkosic with some locally derived material. Some eolian sand
- Qme — Modesto Formation: eolian dune sand forming low hills
- Qr — Riverbank Formation: alluvial sand, gravel, silt, and clay associated with terraces and fans. Dominantly arkosic with some locally derived material
- Qtl — Turlock Lake Formation: alluvial sand, gravel, silt, and clay associated with fans. Dominantly arkosic
- QTnm — North Merced Gravel: thin gravel veneer on a pediment cut across Tertiary and Mesozoic rocks. Locally derived material

TERTIARY

PLIOCENE

- Tl — Laguna Formation: alluvial sand, gravel, and silt associated with fans. Mostly arkosic with some locally derived material

MIOCENE

- Tm — Mehrten Formation: undifferentiated claystone, mudstone, siltstone, sandstone, and conglomerate derived from andesitic sources to the east. Includes minor tuff and mudflows
- Tpm — Table Mountain Latite: porphyritic augite latite lava flow
- Tvs — Valley Springs Formation: undifferentiated claystone, tuffaceous claystone, vitric tuff, and siltstone derived from rhyolitic sources to the east. Includes minor sandstone and conglomerate

OLIGOCENE

- Ti — Ione Formation: quartzose kaolinitic sandstone, kaolinitic claystone, and pebble conglomerate

CRETACEOUS

- Ku — Unnamed marine(?) sedimentary rocks: sandstone, siltstone, and conglomerate

JURASSIC

- Ji — Intrusive metadiabase
- Jm — Merced Falls Slate: undifferentiated slate with minor metasandstone and metatuff
- Jgs — Gopher Ridge Volcanics: undifferentiated silicic and mafic metatuff and metasandstone of volcanic and detrital origin
- Jg — Gopher Ridge Volcanics: undifferentiated silicic to mafic metamorphosed lava flows and pyroclastic deposits intruded locally by hypabyssal and plutonic rocks of dominantly felsic composition

NOTE: Because of the complexity of the geology in places and the scale of the map, areas mapped as one geologic unit may include smaller exposures of other geologic units.

SYMBOLS

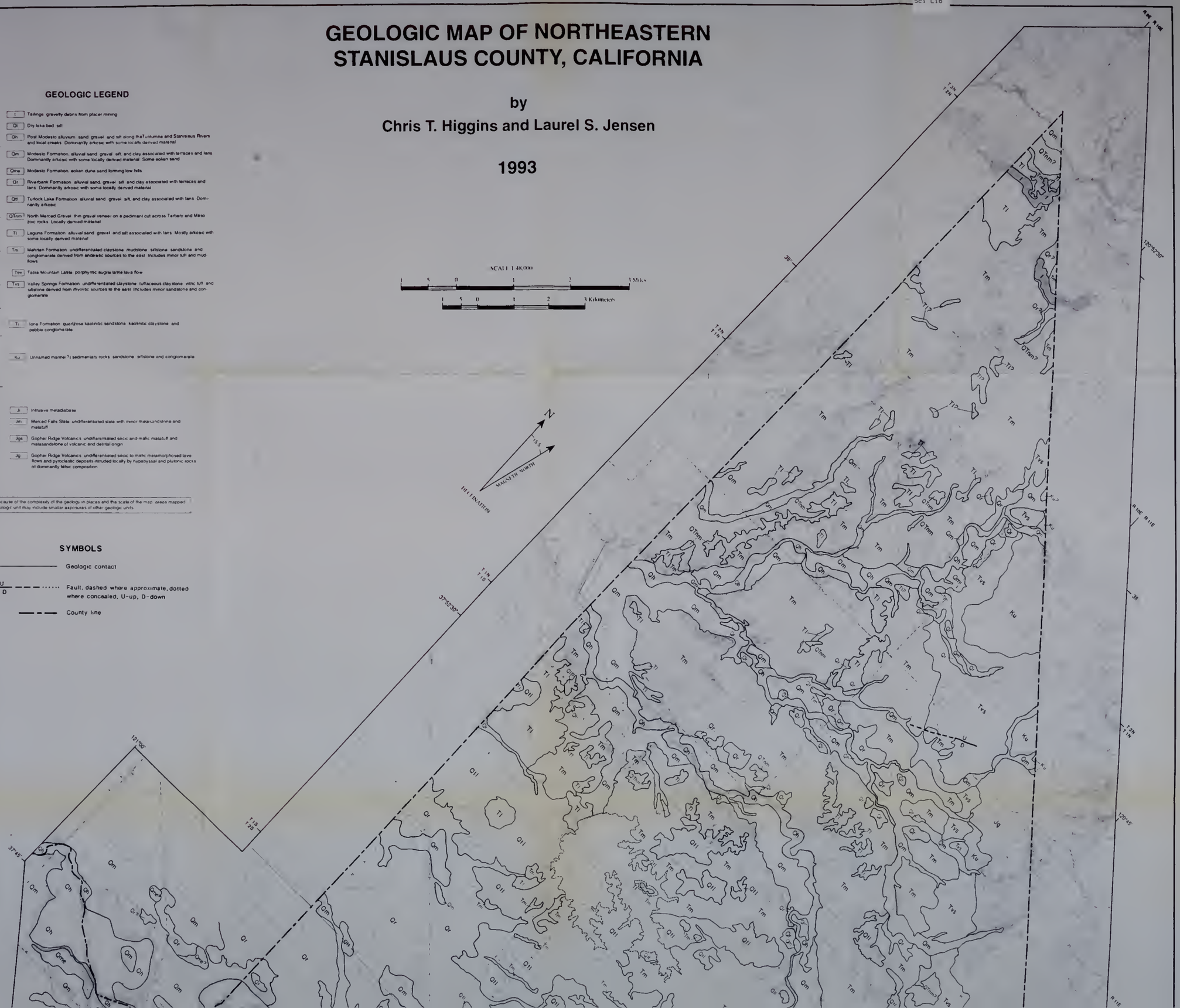
- Geologic contact
- U / D — Fault, dashed where approximate, dotted where concealed. U-up, D-down
- County line

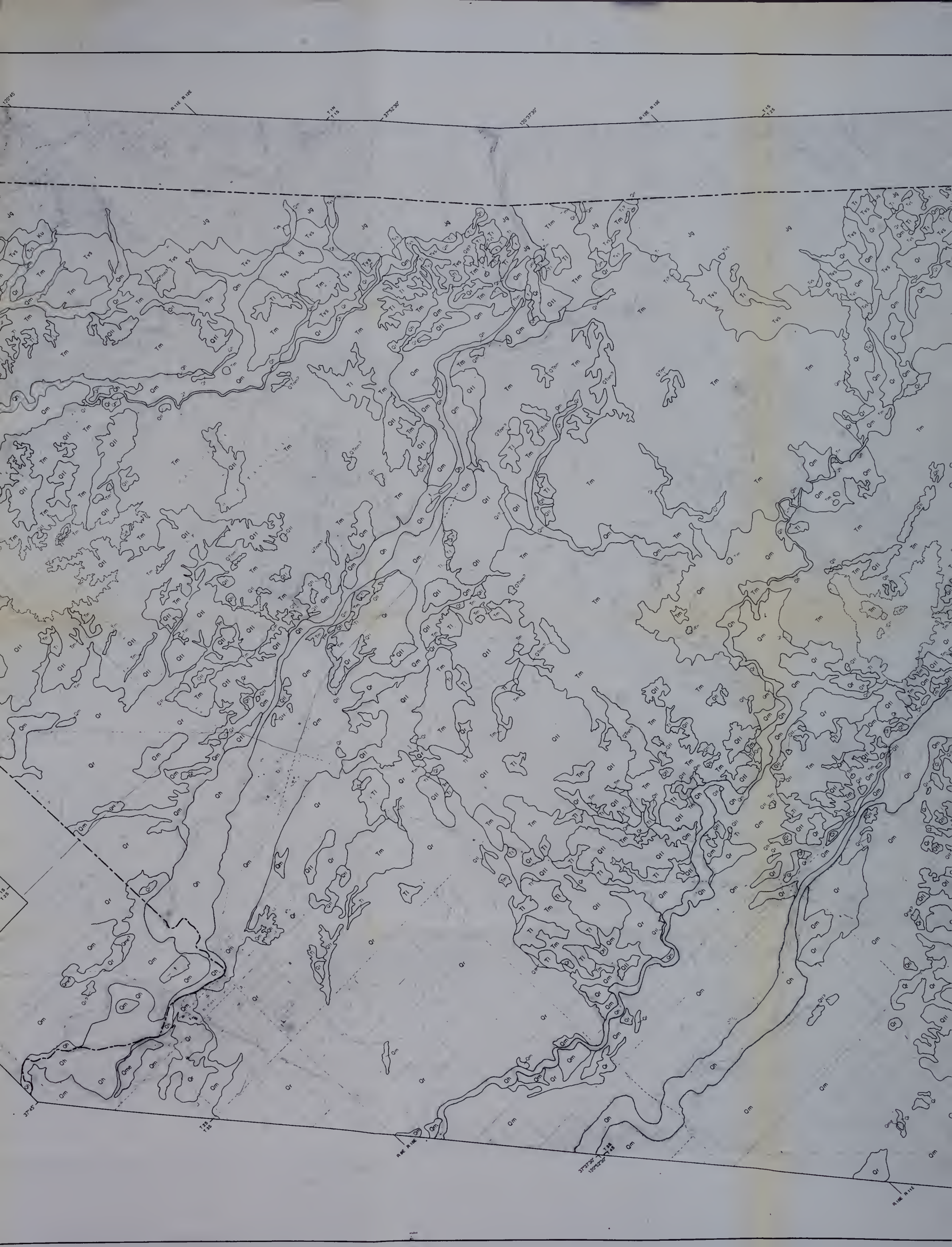
SCALE 1:48,000

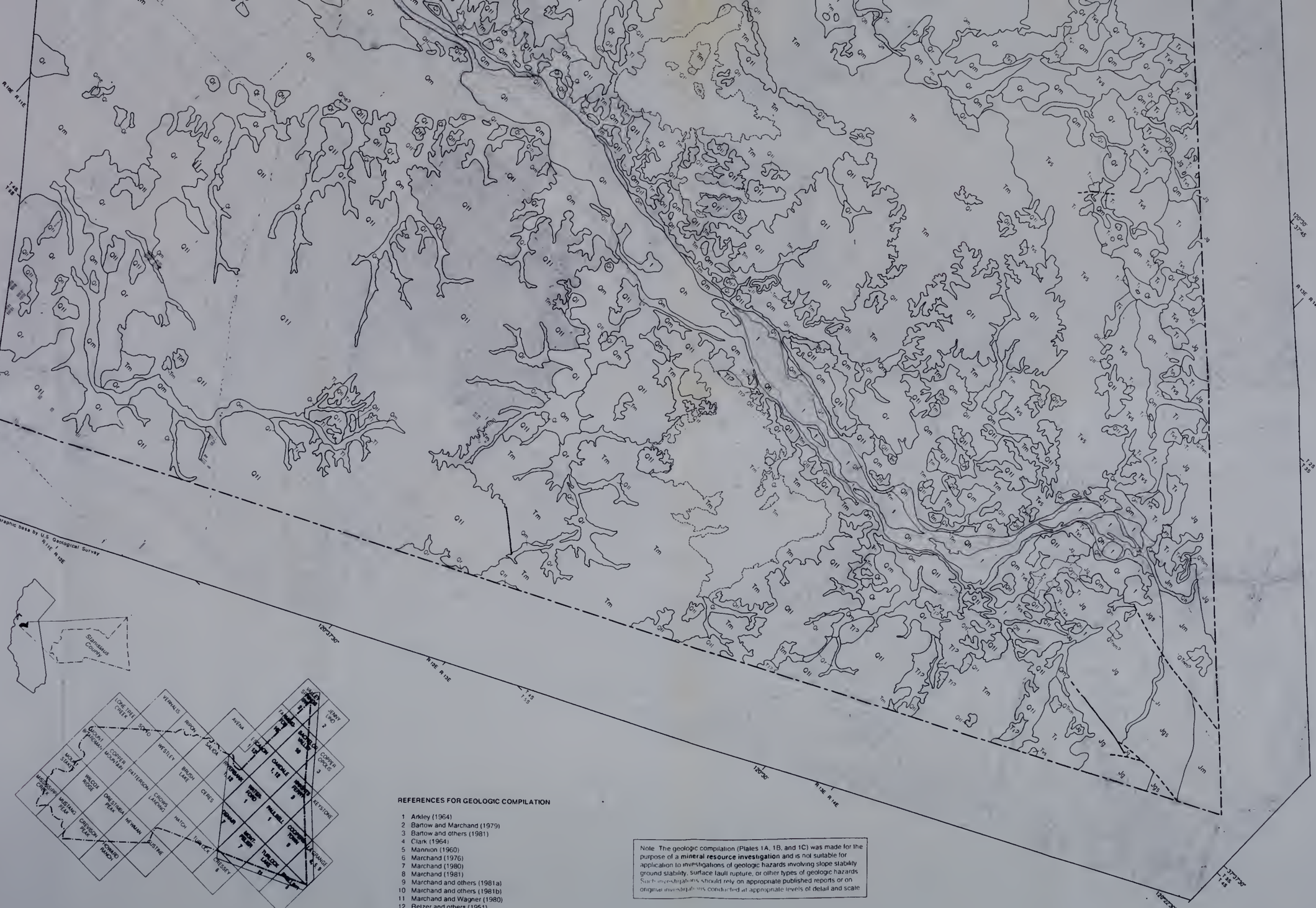
1 0 1 2 3 Miles

1 0 1 2 3 Kilometers

ILLUSTRATION: N, 15.5°, MAGNETIC NORTH




120°45'
PINE RIDGE
T1N
T1S
37°52'30"
120°37'30"
PINE RIDGE
T1S
T2S
37°45'
T2S
T2S
PINE RIDGE
37°37'30"
120°30'
T2S
T2S
PINE RIDGE



Index map of U.S.G.S. 7.5-minute quadrangles and references used for compilation

REFERENCES FOR GEOLOGIC COMPILATION

1 Arkley (1964)
2 Bartow and Marchand (1979)
3 Bartow and others (1981)
4 Clark (1964)
5 Mannion (1960)
6 Marchand (1976)
7 Marchand (1980)
8 Marchand (1981)
9 Marchand and others (1981a)
10 Marchand and others (1981b)
11 Marchand and Wagner (1980)
12 Reizer and others (1951)

Note: The geologic compilation (Plates 1A, 1B, and 1C) was made for the purpose of a **mineral resource investigation** and is not suitable for application to investigations of geologic hazards involving slope stability, ground stability, surface fault rupture, or other types of geologic hazards. Such investigations should rely on appropriate published reports or on original investigations conducted at appropriate levels of detail and scale.

Drafting and layout by Joy A. Sullivan

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JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA - PETE WILSON, GOVERNOR
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MINERAL LAND CLASSIFICATION MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for deposits of aggregate formed by various geologic processes)

by

Don Dupras

1993

SCALE 1:48,000

1 .5 0 1 2 3 Miles

1 .5 0 1 2 3 Kilometers

N

16.5°

MAGNETIC NORTH

DECLINATION

ACTIVE AND PROPOSED AGGREGATE MINES
Southwestern Area
Active and proposed aggregate mine site locations shown as circled numbers on map, e.g. (4)

Mine Site No.	Site Name	Operator	Appendix No.
1 *	Vernalis Site*	Granite Construction Co.	-
2	Zacharias Road Pit North **	Lee White Ranch	14
3	Zacharias Road Pit South **	Lee White Ranch	15
4	Orestimba Pit	Frank B. Marks & Sons, Inc.	90
5	Stuhr Road Pit West	Frank B. Marks & Sons, Inc.	91
6	Stuhr Road Pit East	Frank B. Marks & Sons, Inc	91
7.	Garzas Creek Pit	County of Merced	99

* Proposed mining site
** Produces base aggregate only

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THE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION - EDWARD G. HEIDIG, DIRECTOR

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A33
no. 173
plate 2A
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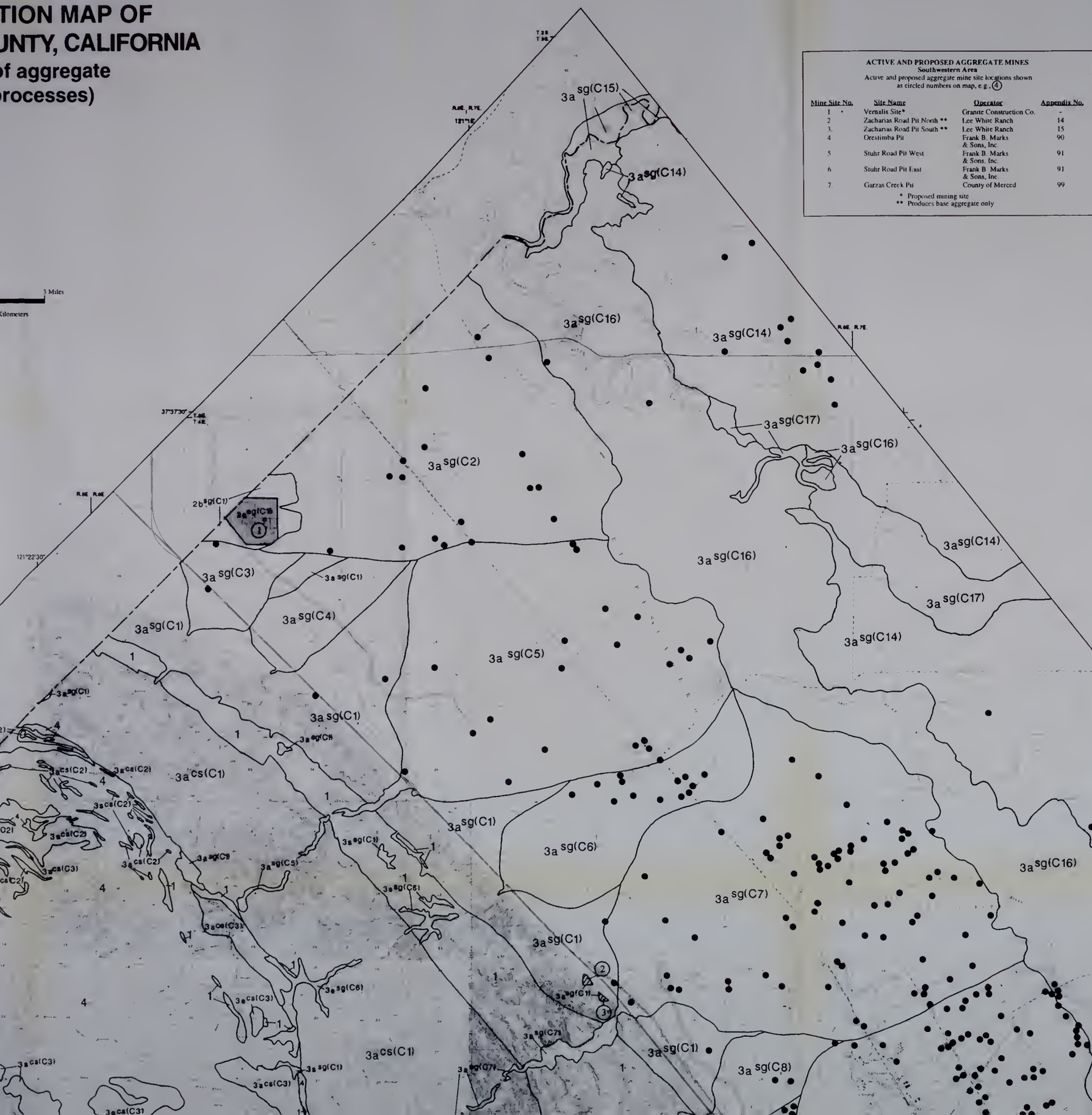
TION MAP OF
UNTY, CALIFORNIA
of aggregate
rocesses)



ACTIVE AND PROPOSED AGGREGATE MINES
Southwestern Area
Active and proposed aggregate mine site locations shown as circled numbers on map, e.g., (4)

Mine Site No.	Site Name	Operator	Appendix No.
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7	Garzas Creek Pit	County of Merced	99

* Proposed mining site
** Produces base aggregate only

RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources. *

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits.

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Areas containing known mineral occurrences of undetermined mineral resource significance. Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources. *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

Specific Mineral Resource Zones are discussed in the text under the following superscripts:

sg(C#): Areas classified for concrete aggregate (sand and gravel)

sg(B#): Areas classified for base aggregate (sand and gravel)

cs(C#): Areas classified for concrete aggregate (crushed stone)

SYMBOLS

- Mineral Resource Zone boundary
- County line
- Drill hole
- Areas permitted for aggregate mining
- Areas undergoing the permitting process for aggregate mining

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James F. Davis
STATE GEOLOGIST

3a cs(C1)
3a sg(C1)
3a sg(C8)
3a sg(C9)
3a sg(C10)
3a sg(C11)
3a cs(C3)
3a sg(C7)
3a sg(C12)
3a sg(C13)
2b sg(C2)
2a sg(C2)
2b sg(C3)
3a sg(C6)
3a cs(C11)
3a cs(C13)

3a sg(C1)
3a cs(C1)
3a sg(C11)
3a sg(C12)
3a sg(C13)
3a sg(C14)
3a sg(C16)
3a sg(C9)
3a sg(C8)
3a sg(C7)
3a cs(C3)
2b sg(C2)
121°00'W
120°52'30"W
37°15'
37°07'30"

Topographic base by U.S. Geological Survey 1972

121°15'E
R4E T7E

121°22'30"
R4E T7E

37°07'30"

37°07'30"

121°07'30"

R7E R8E

T8S

Stanislaus County

Index map of U.S.G.S. 7.5-minute quadra

LONE TREE CREEK | SOLYO | WESTLEY | BRUSH LAKE | CERES

LAUCOUNT SQUAW | COPPER MOUNTAIN | MATTERSON | CROWS LANDING | PATTCH

MOUNT STAGES | WILCOX RIDGE | ONESTRABA PEAK | NEWMAN | WESTLAKE

MISSISSIPPI CREEK | MUSTANG PEAK | CREVISON PEAK | HOWARD RANCH

VERNALIS | RIPON | SALIDA | AVENA | ESCALON

RIVERBANK | HUGHSON | TURLOCK SPRINGS SW

3a sg(C1)
3a cs(C1)
2b sg(C3)
2b sg(C2)
2a sg(C2)
4
5
6
7

Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

Drafting and layout by Joy A. Sullivan

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no. 173
plate 2B
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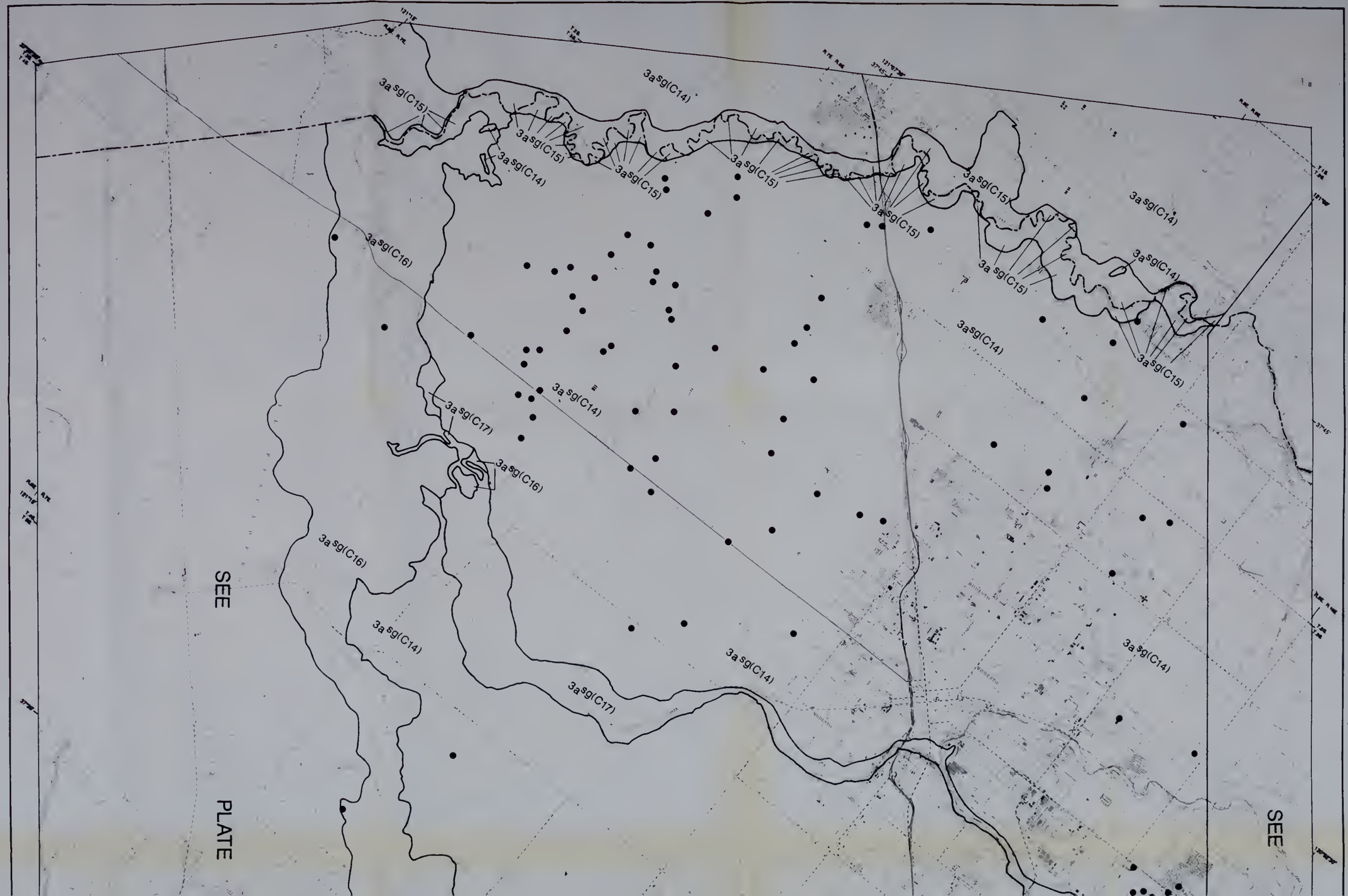
SPECIAL REPORT 173
PLATE 2B
AGGREGATE CENTRAL



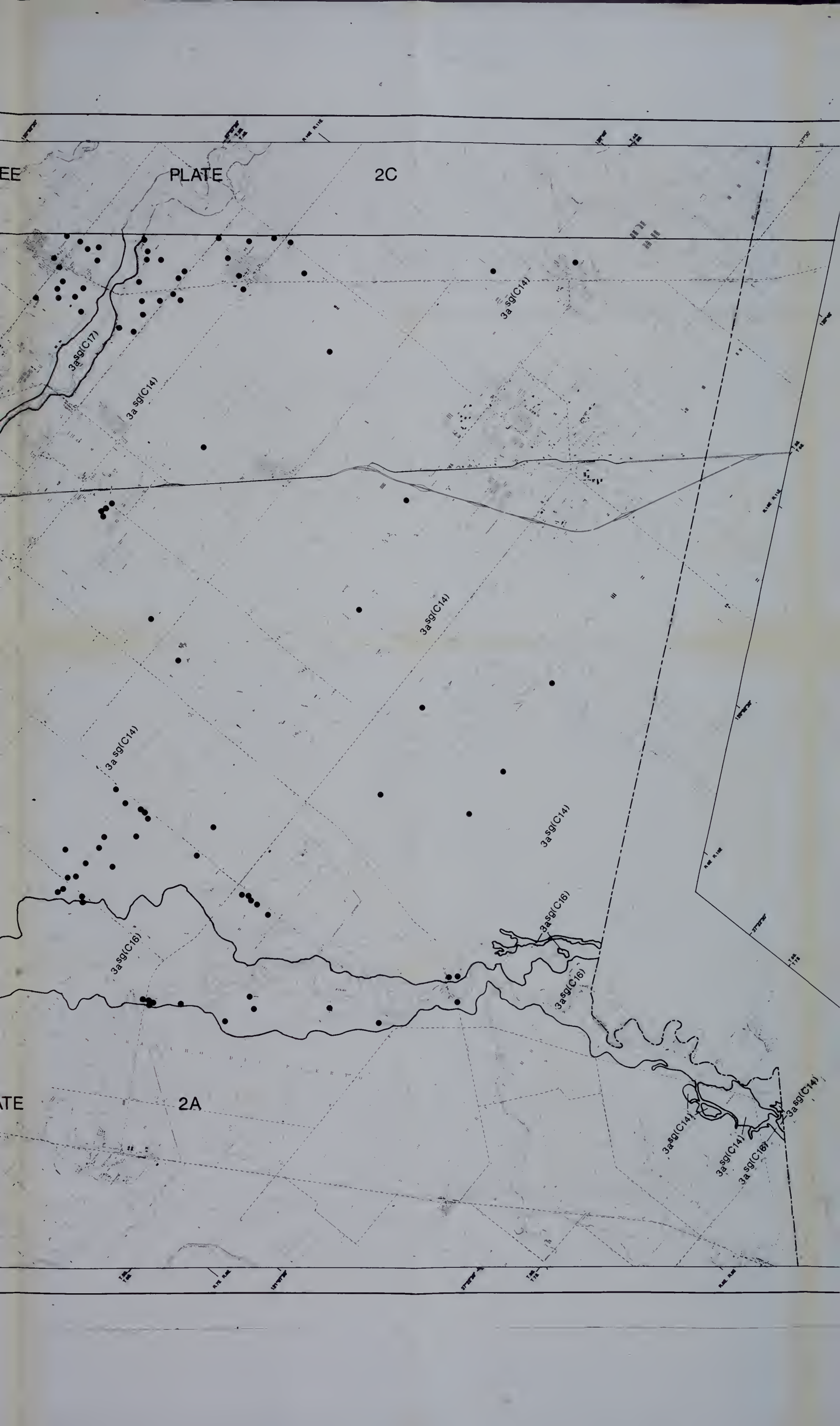

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PLATE
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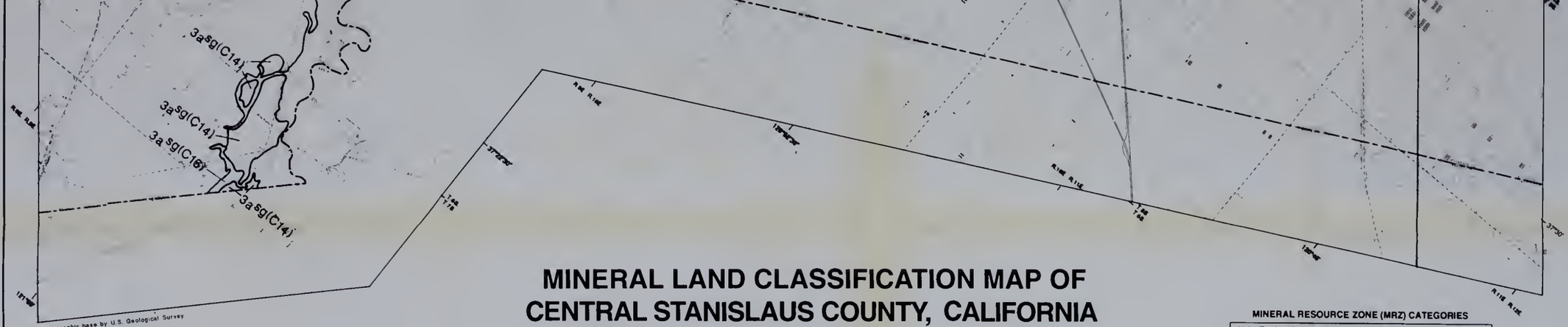
3a sg(C14)
TE
2A



Topographic base by U.S. Geological Survey

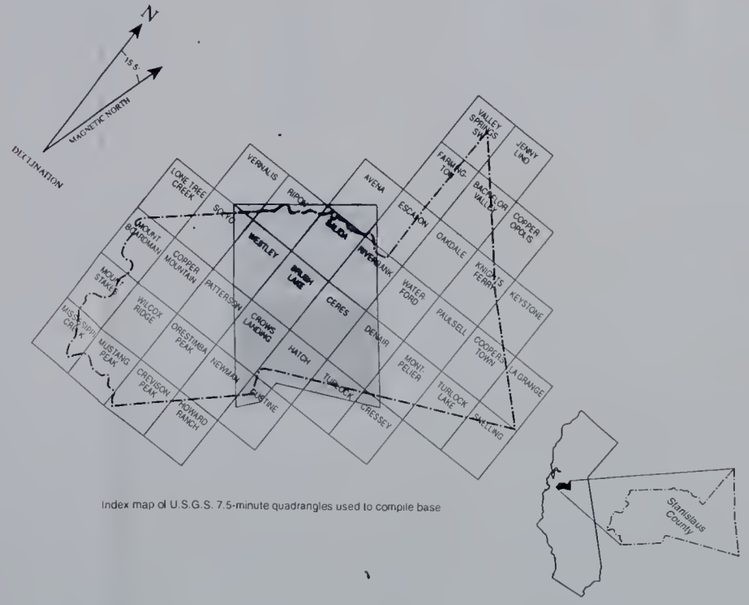
MINERAL LAND CLASSIFICATION MAP OF CENTRAL STANISLAUS COUNTY, CALIFORNIA

(Areas classified for deposits of aggregate formed by various geologic processes)

by

Don Dupras

1993



Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

SCALE 1:48,000

1 5 0 1 2 3 Miles

1 5 0 1 2 3 Kilometers

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James F. Davis
STATE GEOLOGIST

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

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Specific Mineral Resource Zones are discussed in the text under the following superscripts:

sg(C#): Areas classified for concrete aggregate (sand and gravel)

SYMBOLS

Mineral Resource Zone boundary

County line

Drill hole

Drafting and layout by Joy A. Sullivan and James D. Williams

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no. 173
plate 2C
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PLATE 2C
AGGREGATE NE

MINERAL LAND CLASSIFICATION MAP OF NORTHEASTERN STANISLAUS COUNTY

(Areas classified for deposits of aggregate formed by various geologic processes)

by
Don Dupras

1993

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources.*

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits.

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Areas containing known mineral occurrences of undetermined mineral resource significance. Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources.*

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

Specific Mineral Resource Zones are discussed in the text under the following superscripts:

ag(C#): Areas classified for concrete aggregate (sand and gravel)

cs(C#): Areas classified for concrete aggregate (crushed stone)

SYMBOLS

- Mineral Resource Zone boundary
- County line
- Drill hole
- Areas permitted for aggregate mining
- Areas undergoing the permitting process for aggregate mining

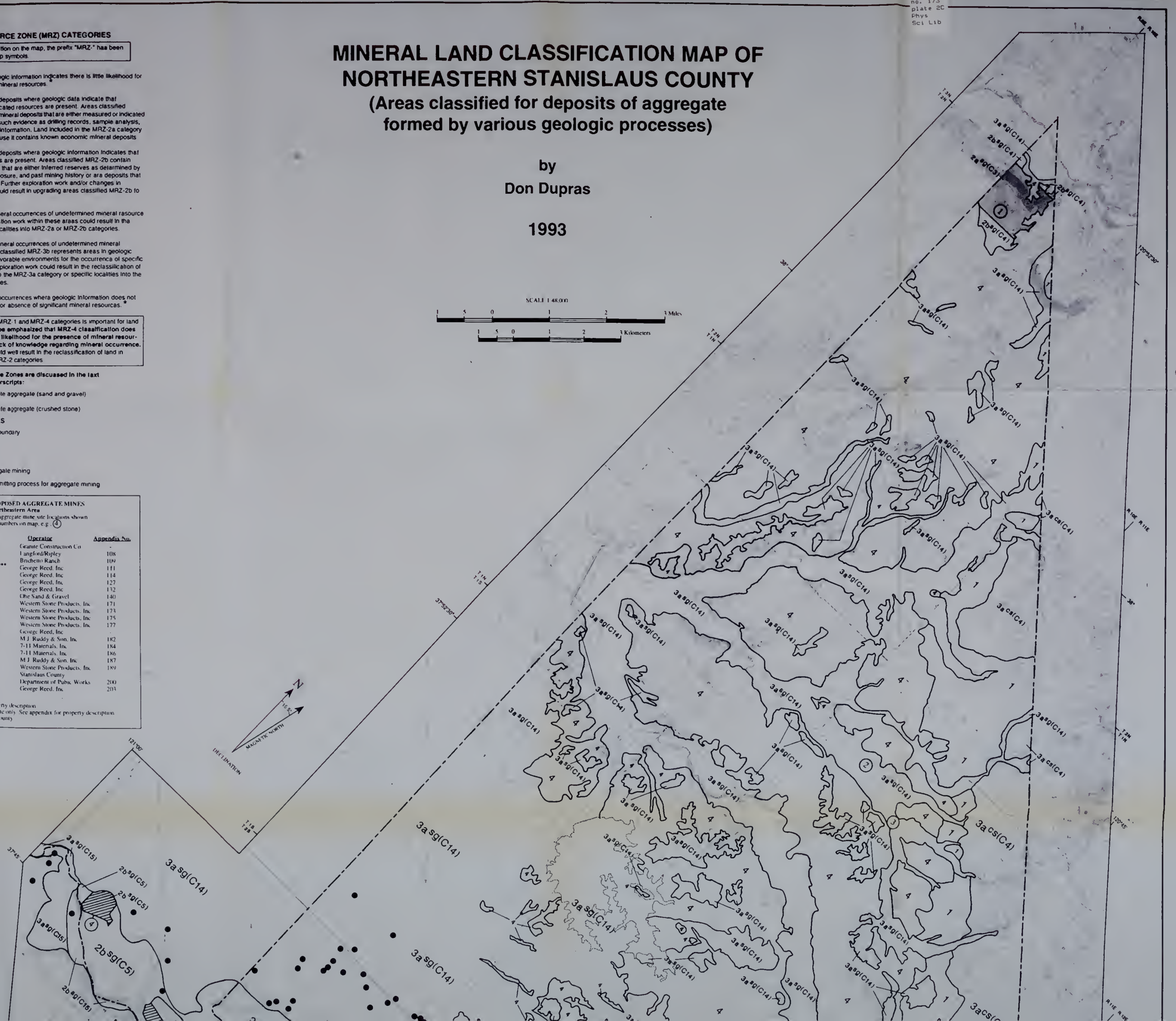
ACTIVE AND PROPOSED AGGREGATE MINES
Northeastern Area

Active and proposed aggregate mine site locations shown as circled numbers on map, e.g. (4)

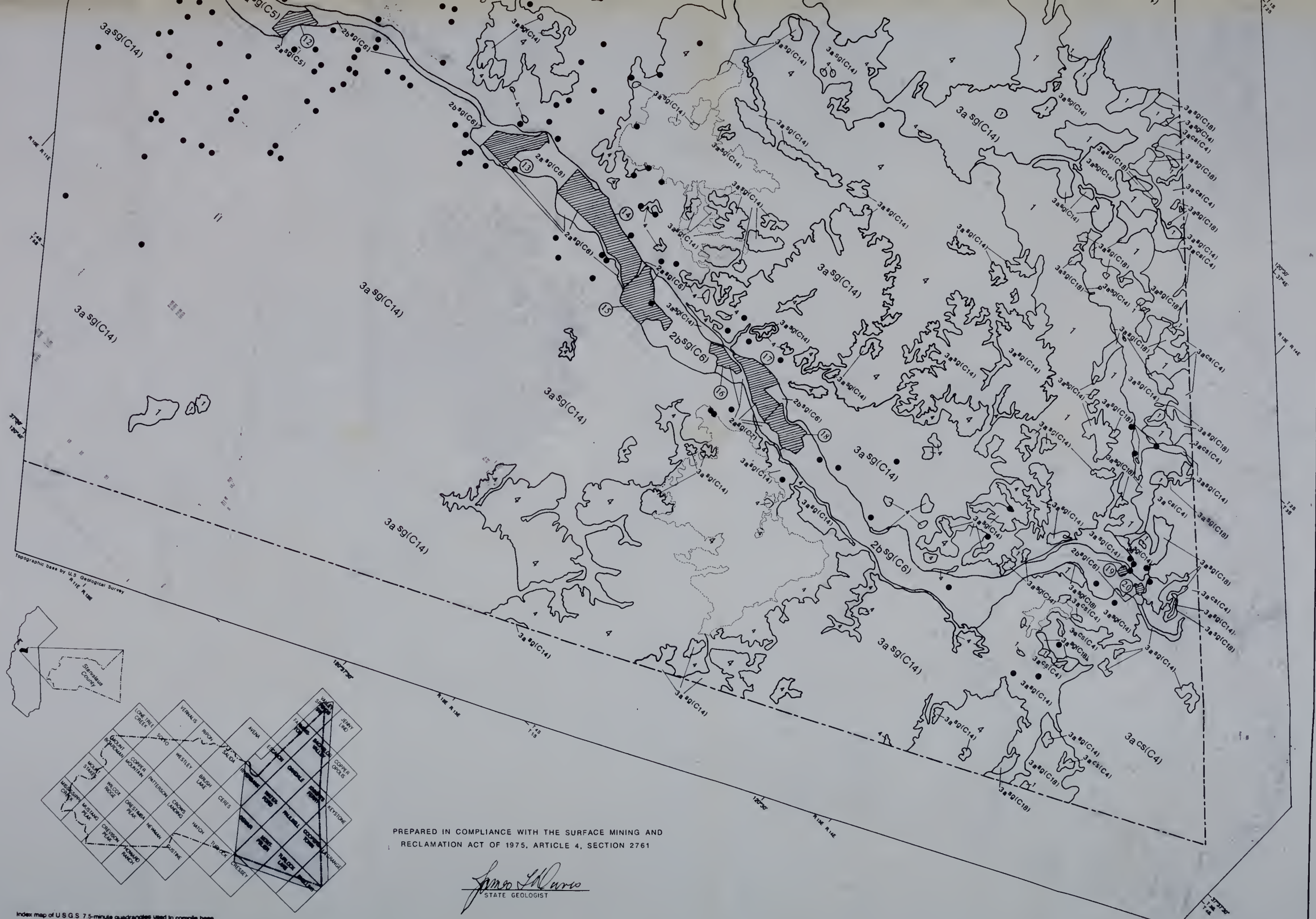
Mine Site No.	Site Name	Operator	Appendix No.
1	Mueller Ranch Site*	Granite Construction Co.	-
2	Dunton Road Site**	Langford/Ripley	108
3	Shirley Creek Site***	Brichetto Ranch	109
4	Munn & Perkins Pit****	George Reed, Inc.	111
5	Riverbank Pit****	George Reed, Inc.	114
6	Ardis Pit North	George Reed, Inc.	127
7	Hodge Ranch Pit	George Reed, Inc.	132
8	Williams Ranch Pit	Ohe Sand & Gravel	140
9	Schmidt Pit	Western Stone Products, Inc.	171
10	Landmark Pit	Western Stone Products, Inc.	173
11	Warner Pit	Western Stone Products, Inc.	175
12	Hickman Pit	Western Stone Products, Inc.	177
13	Waterford Site*	George Reed, Inc.	-
14	Waterford Pit	M.J. Ruddy & Son, Inc.	182
15	Waterford Pit	7-11 Materials, Inc.	184
16	Roberts Ferry Pit	7-11 Materials, Inc.	186
17	La Grange Pit	M.J. Ruddy & Son, Inc.	187
18	Cree Ranch Pit	Western Stone Products, Inc.	189
19	La Grange Pit	Stanislaus County Department of Public Works	200
20	Sarah Reeves Pit	George Reed, Inc.	203

* Proposed mining site
** See appendix for property description
*** Produces base aggregate only. See appendix for property description
**** Sites in San Joaquin County

SCALE 1:48,000
1 5 0 1 2 3 Miles
1 5 0 1 2 3 Kilometers



3a sg(C14)
2b sg(C5)
3a cs(C4)
2b sg(C6)
2a sg(C5)
3a sg(C17)
3a sg(C18)
3a cs(C5)
R.11E. R.12E.
T.2S. T.1S.
37°37'30"
120°52'30"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2b sg(C6)
3a cs(C4)
2a sg(C5)
2a sg(C6)
2a sg(C7)
3a sg(C18)
3a cs(C18)
Topographic base by U.S. Geological Survey
PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND
RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761
STATE GEOLOGIST
Index map of U.S.G.S. 7.5-minute quadrangles used to compile base
Drafting and layout by Joy A. Sullivan

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA - PETE WILSON, GOVERNOR
THE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION - EDWARD G. HEIDIG, DIRECTOR

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A33
no. 173
plate 3
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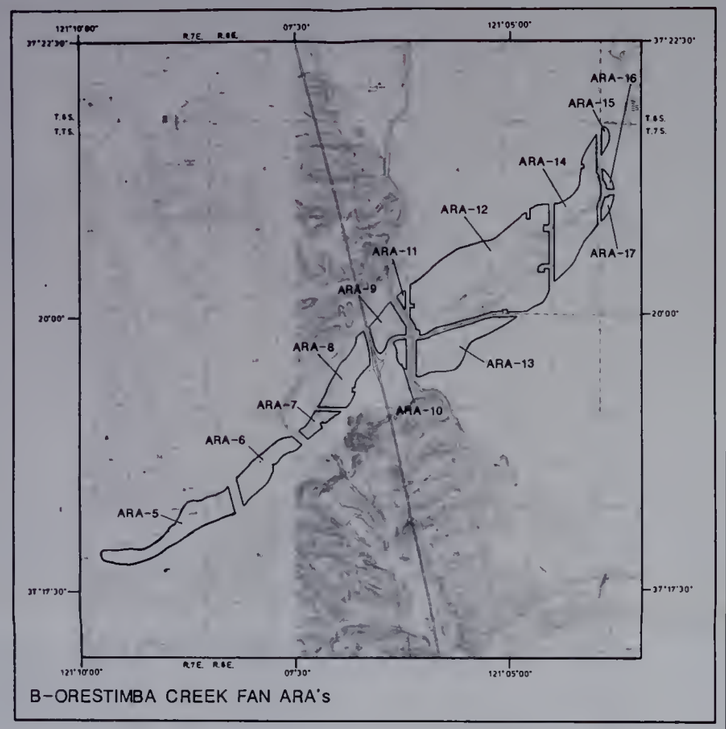
SPECIAL REPORT 173
PLATE 3
AGGREGATE RESOURCE AREAS

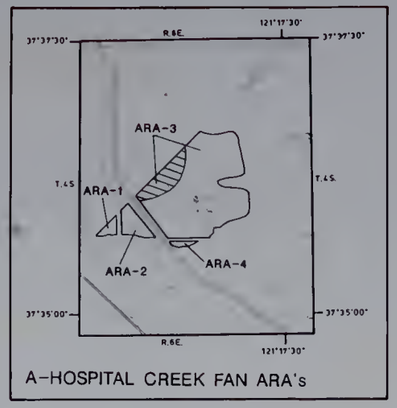
AGGREGATE RESOURCE AREAS OF STANISLAUS COUNTY, CALIFORNIA

by
Don L. Dupras

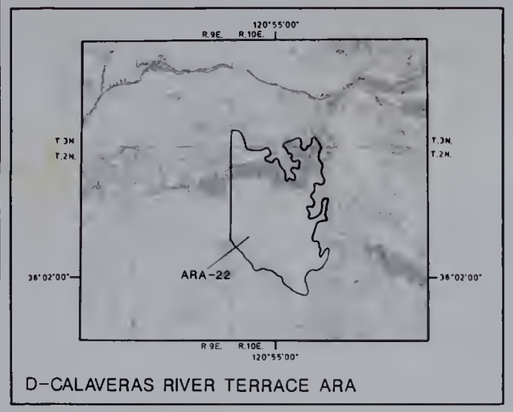
1993



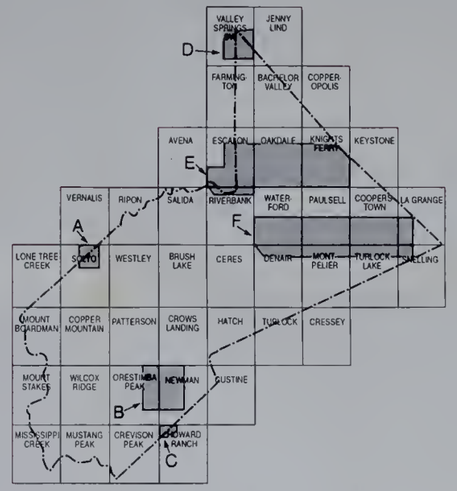
B–ORESTIMBA CREEK FAN ARA's



A–HOSPITAL CREEK FAN ARA's



D–CALAVERAS RIVER TERRACE ARA



Index map of U.S.G.S. 7.5-minute quadrangles used to compile bases.

Topographic base maps by U.S. Geological Survey.

SCALE 1:48,000

1 5 0 1 2 3 Miles

1 5 0 1 2 3 Kilometers

SYMBOLS

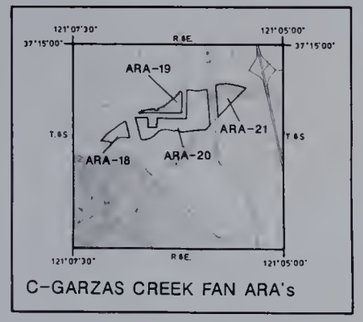
Aggregate Resource Area (ARA)*

Portion of ARA previously shown as a Designation Area by the State of California Mining and Geology Board.**

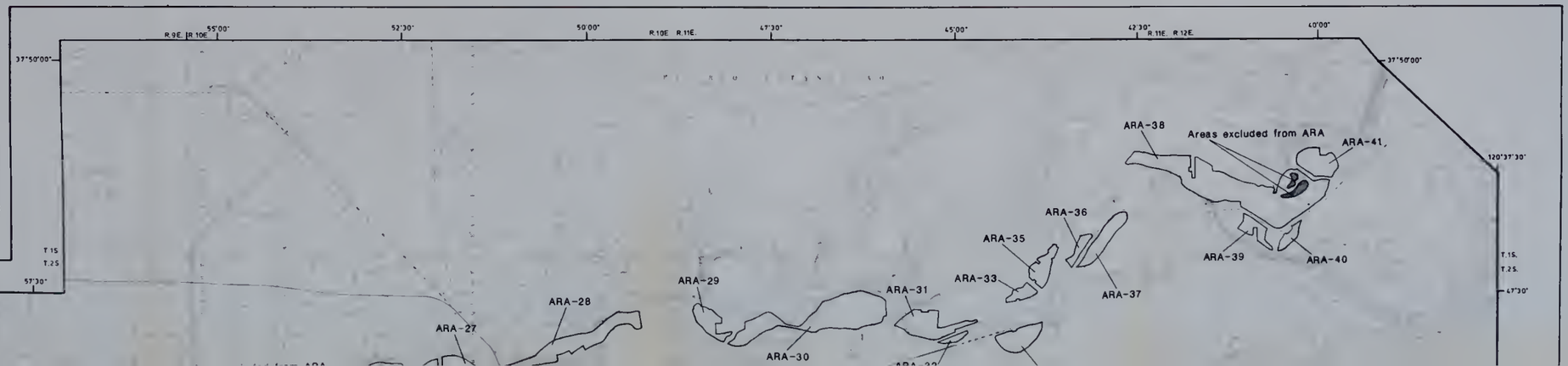
*See text for explanation of Aggregate Resource Area.
**See text for explanation of Designation Area.

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

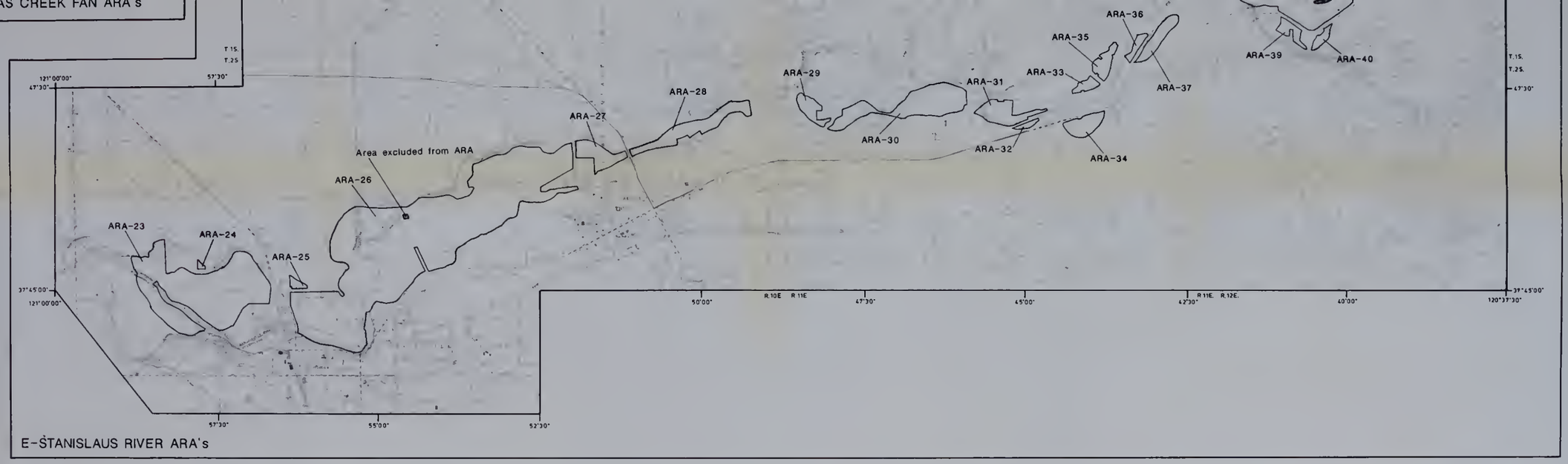
James F. Davis
STATE GEOLOGIST



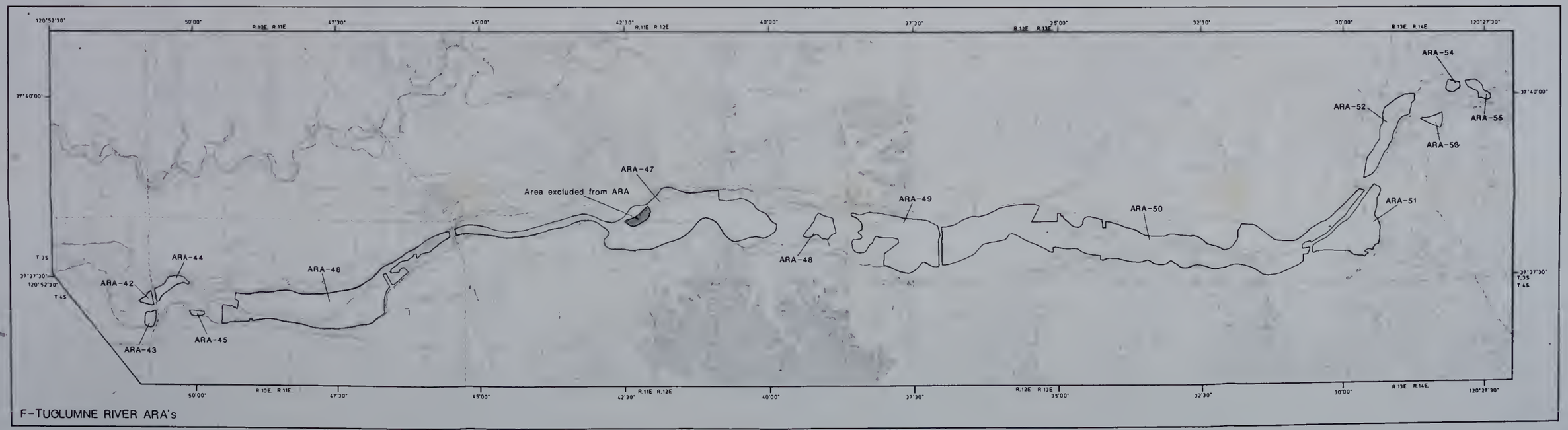
C–GARZAS CREEK FAN ARA's



C-GARZAS CREEK FAN ARA's



E-STANISLAUS RIVER ARA's



F-TUOLUMNE RIVER ARA's

Drafted by James D. Williams

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA - PETE WILSON, GOVERNOR
THE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION - EDWARD G. HEIDIG, DIRECTOR

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentetion on the map, the prefix "MRZ-" hes been eliminated from mep symbols.

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MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Arees classified MRZ-2b contain discovered mineral deposits thet are either inferred reserves as determined by limited sample enalysis, exposure, end past mining history or ere deposits that presently are subeconomic. Further exploration work and/or chenges in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Arees containing known mineral occurrences of undetermined mineral resource significance. Further exploretion work within lhese areas could result in lhe reclassificetion ol specific localities into MRZ-2e or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appeer to be levorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources *

* Tne distinction between the MRZ-1 and MRZ-4 categories is important lor land use considerations. **It must be emphesized thet MRZ-4 classification does not imply thet there is little likelihood for the presence of minerel resources, but rather there is a lack of knowledge regarding minerel occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 ol MRZ-2 categories

Mineral Resource Zones are discussed in the text under the following **superscripts**. Those **superscripts** with **numbers** (shown on the map) refer to unique areas with particular mineral resource characteristics specifically described in the text. Those without numbers refer to areas with mineral resource charactenstics described in e general way in lhe text.

I(B): Areas classified lor deposits of bentonitic clay

I(D#): Areas classified lor deposits of diatomite.

I(M#): Areas classified lor deposits ot magnesite

I(Q#): Areas classified for deposits ol quartz (silica).

I(S#): Areas classified for deposits of specialty sand

I(S,K#): Areas classified lor deposits of specialty sand and kaolinitic clay

I(Sh#): Areas classified for deposits of expansible shale

I(St,Sh#): Areas classified for deposits ol dimension stone and expansible shale

I: Arees classified for deposits of industrial minerals in general

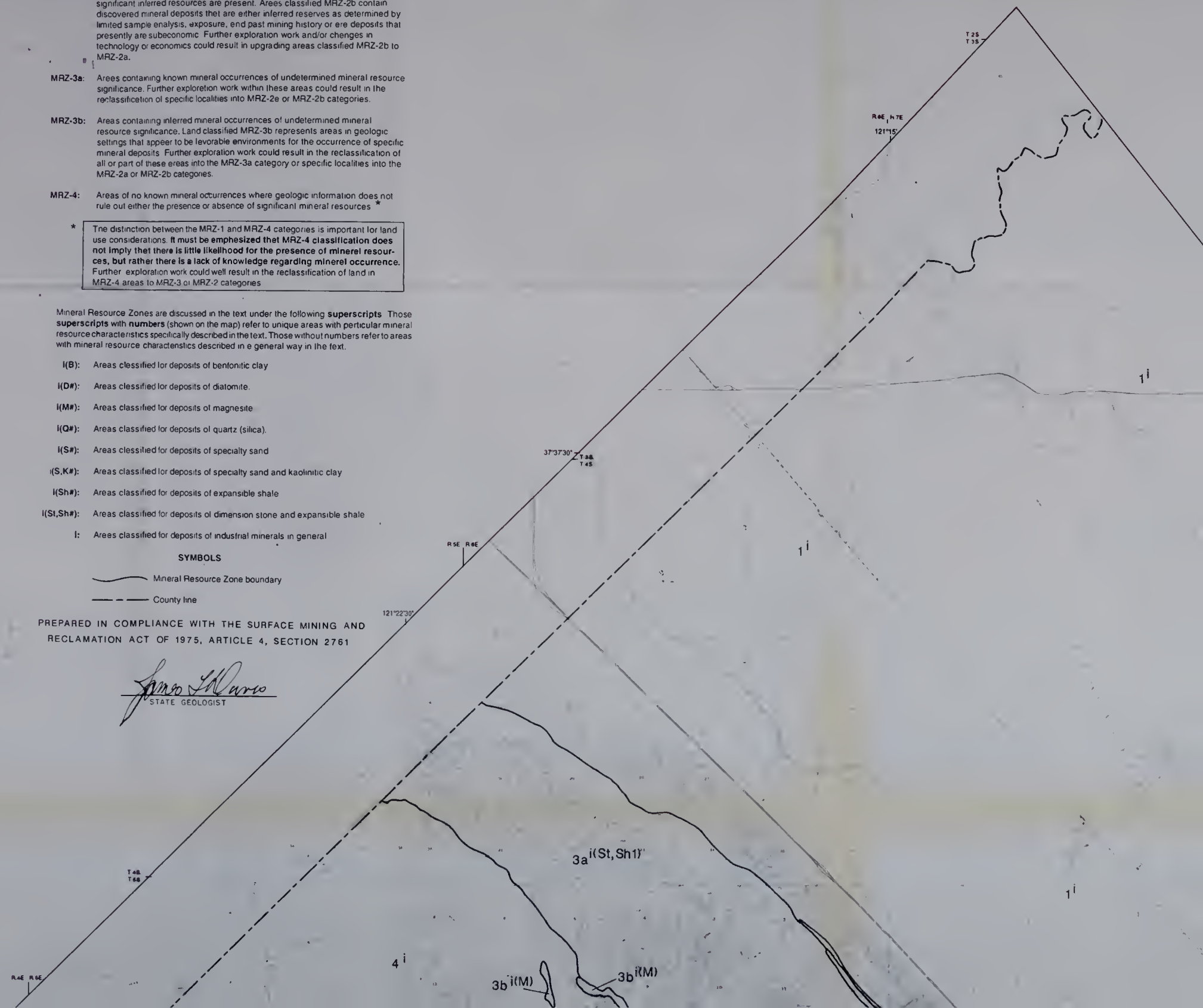
SYMBOLS

Mineral Resource Zone boundary

County line

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James F. Davis
STATE GEOLOGIST



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HE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION - EDWARD G. HEIDIG, DIRECTOR

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plate 4A
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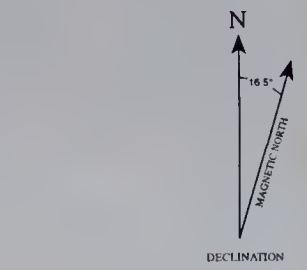
SPECIAL REPORT 173
PLATE 4A
INDUSTRIAL MINERALS SW

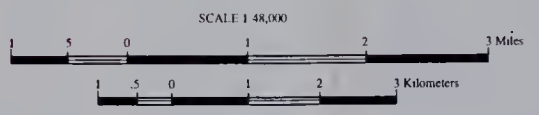
MINERAL LAND CLASSIFICATION MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for industrial minerals formed by various geologic processes, generally sedimentary)

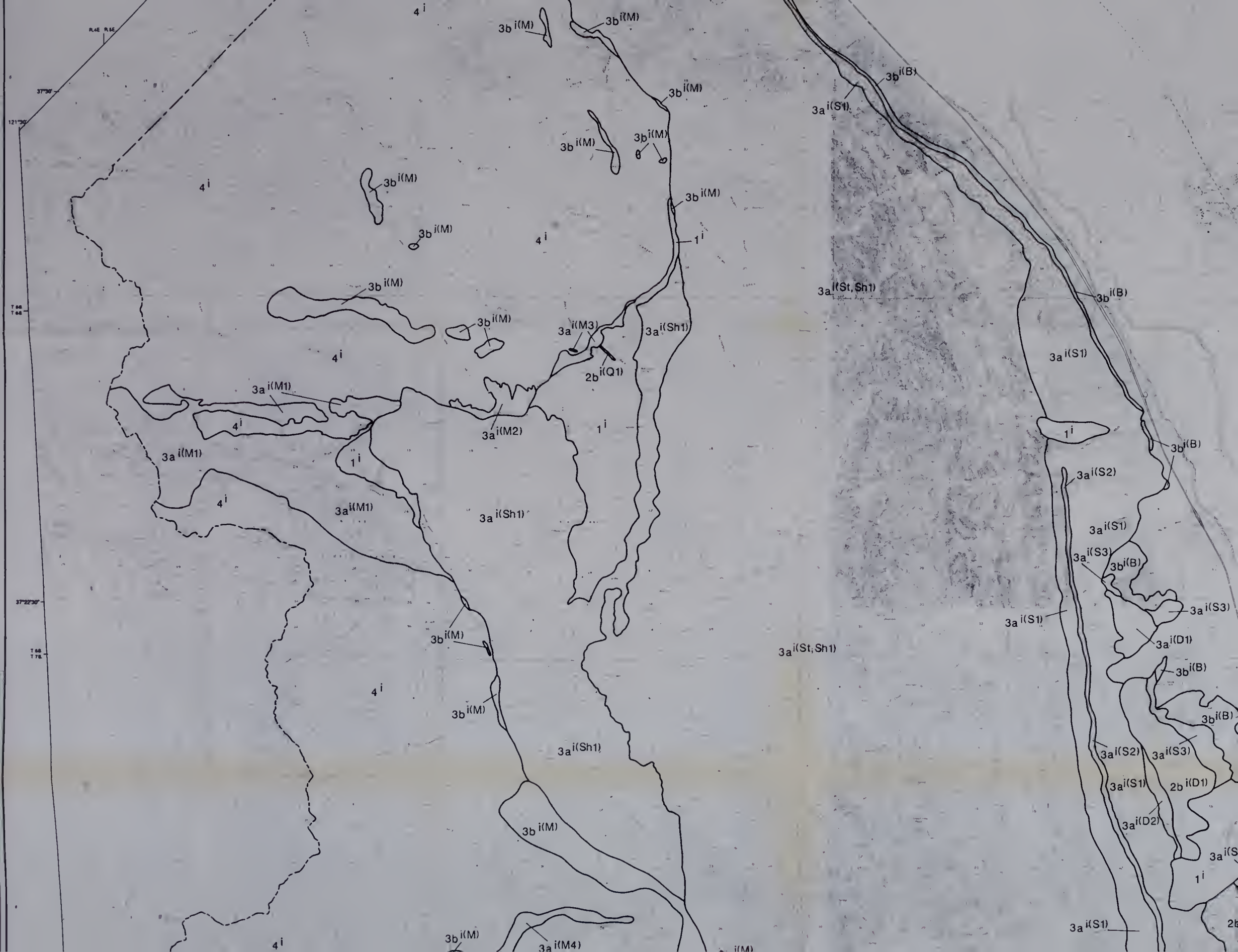
by
Chris T. Higgins

1993





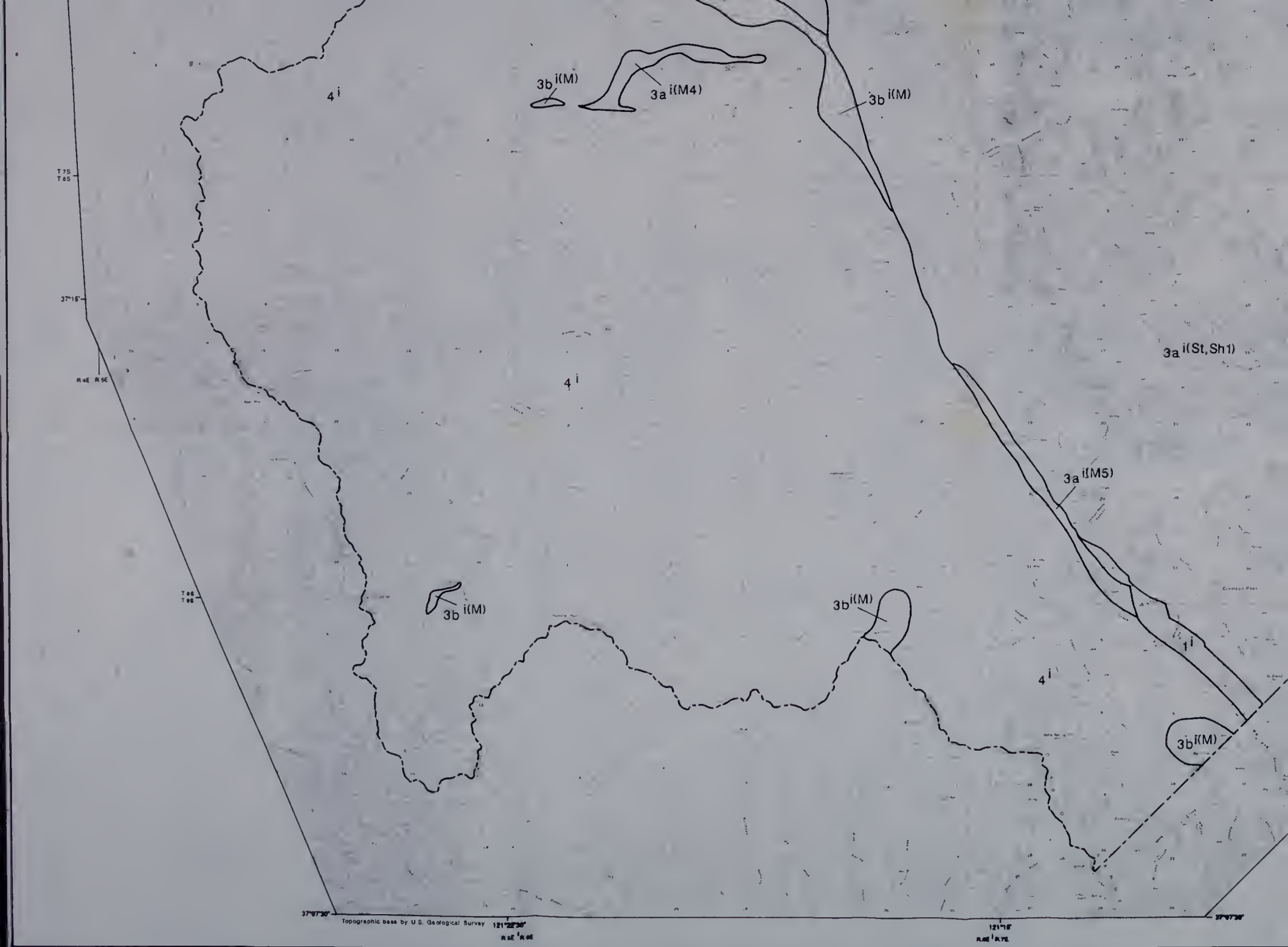
All of central Stanislaus County between this line and the western boundery of Plate 4B is classified 1^{i} for industrial minerals.

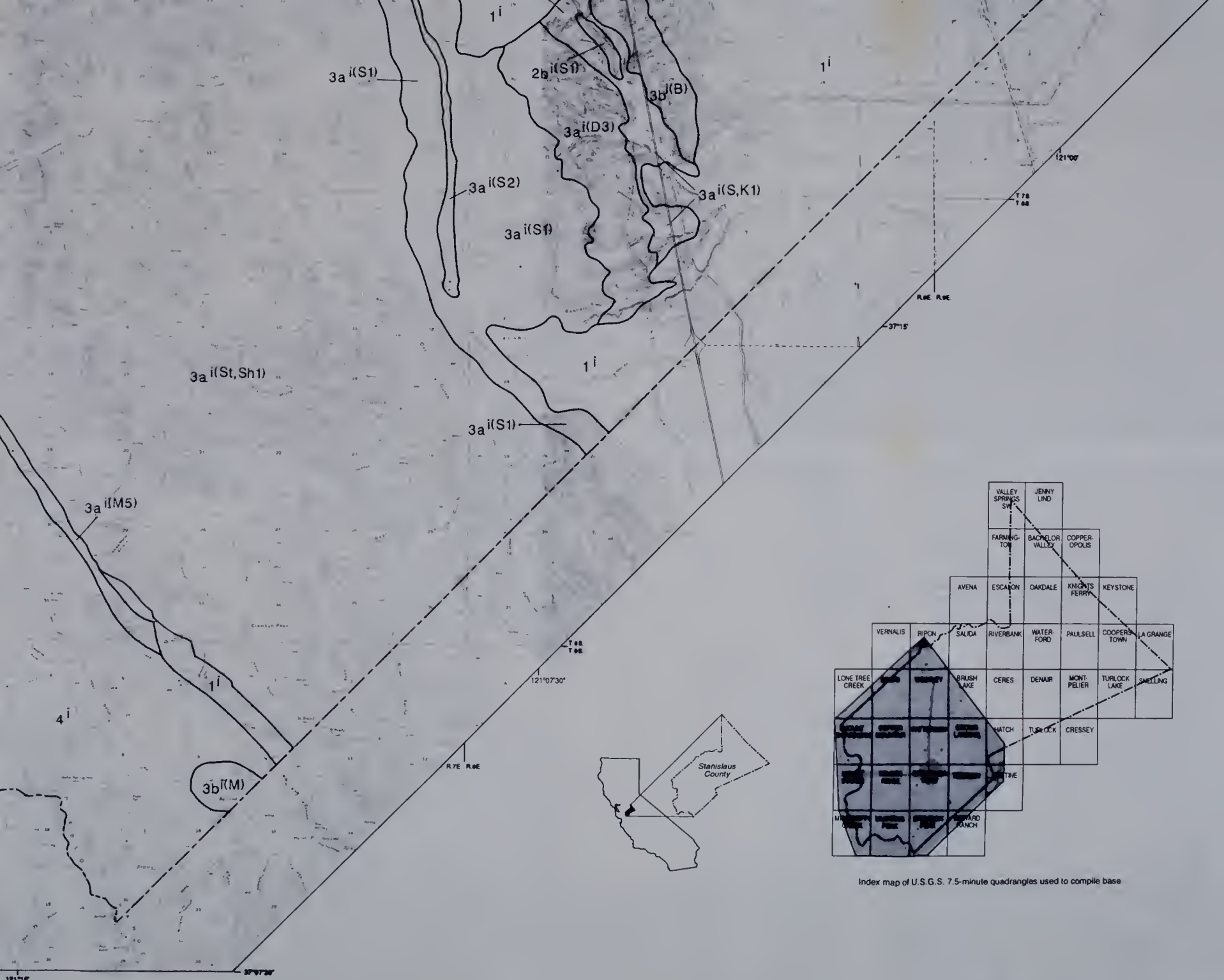

4 i
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
3b i(M)
1 i
3a i(St, Sh1)
3b i(B)
3a i(S1)
3b i(B)
3a i(S1)
3a i(M3)
3a i(Sh1)
2b i(Q1)
3a i(M1)
3a i(M2)
1 i
3a i(M1)
3a i(M1)
3a i(Sh1)
3a i(Sh1)
3a i(St, Sh1)
3a i(S2)
3a i(S1)
3a i(S3)
3b i(B)
3a i(S1)
3a i(S3)
3a i(D1)
3b i(B)
3b i(B)
3a i(S2)
3a i(S3)
3a i(S1)
2b i(D1)
3a i(D2)
1 i
3a i(S1)
3b i(M)
3a i(M4)

All of central Stanislaus County between this line and the western boundary of Plate 4B is classified 1^i for industrial minerals.

121°00'
37°30'

$3b^{i(M)}$
$3b^{i(M)}$
$3b^{i(M)}$
1^i
$3a^{i(Sh1)}$
$3a^{i(St,Sh1)}$
$3a^{i(St,Sh1)}$
$3a^{i(S1)}$
$3b^{i(B)}$
$3a^{i(S1)}$
$3b^{i(B)}$
$3b^{i(B)}$
$3a^{i(S1)}$
$3a^{i(S2)}$
$3a^{i(S1)}$
$3a^{i(S3)}$
$3b^{i(B)}$
$3a^{i(S3)}$
$3a^{i(D1)}$
$3b^{i(B)}$
$3b^{i(B)}$
$3a^{i(S2)}$
$3a^{i(S3)}$
$3a^{i(S1)}$
$2b^{i(D1)}$
$3a^{i(D2)}$
$3a^{i(S,K1)}$
$3b^{i(B)}$
1^i
$2b^{i(S1)}$
$3a^{i(S1)}$
1^i
1^i
1^i
1^i
1^i


4 i
3b i(M)
3a i(M4)
3b i(M)
3a i(St,Sh1)
4 i
3a i(M5)
3b i(M)
3b i(M)
1 i
4 i
3b i(M)
T7S
T8S
37°18'
R4E R5E
T8S
T9S
37°07'30"
Topographic base by U.S. Geological Survey
121°22'30"
R5E R6E
121°15'
R6E R7E
37°07'30"



Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

Drafting and layout by J.A. Sullivan and E.L. Foster

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA - PETE WILSON, GOVERNOR
THE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
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SPECIAL REPORT 173
PLATE 4B
INDUSTRIAL MINERALS NE

MINERAL LAND CLASSIFICATION MAP OF NORTHEASTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for industrial minerals formed by various geologic processes, generally sedimentary)

by
Chris T. Higgins

1993

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

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I(B): Areas classified for deposits of bentonitic clay.

I(D#): Areas classified for deposits of diatomite.

I(RK): Areas classified for deposits of residual kaolinitic clay

I(S#): Areas classified for deposits of specialty sand

I(St#): Areas classified for deposits of dimension stone

I(K,S#): Areas classified for deposits of kaolinitic clay and specialty sand

I(K,St#): Areas classified for deposits of sedimentary kaolinitic clay and specialty sand

I(K,S,St#): Areas classified for deposits of sedimentary kaolinitic clay, specialty sand, and dimension stone.

I: Areas classified for deposits of industrial minerals in general.

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James F. Davis
STATE GEOLOGIST

SCALE 1:48,000

1 .5 0 1 2 3 Miles
1 .5 0 1 2 3 Kilometers

SYMBOLS

- Mineral Resource Zone boundary
- County line

DECLINATION — MAGNETIC NORTH

All of central Stanislaus County between this line and the eastern boundary of Plate 4A is classified 1i for industrial minerals.

3b i(B)

3b i(RK)

3b i(K,S)

3a i(K,S,St1)

3a i(K,S,St)

3a i(St)

3a i(RK)

3b i(K1)

3a i(St1)

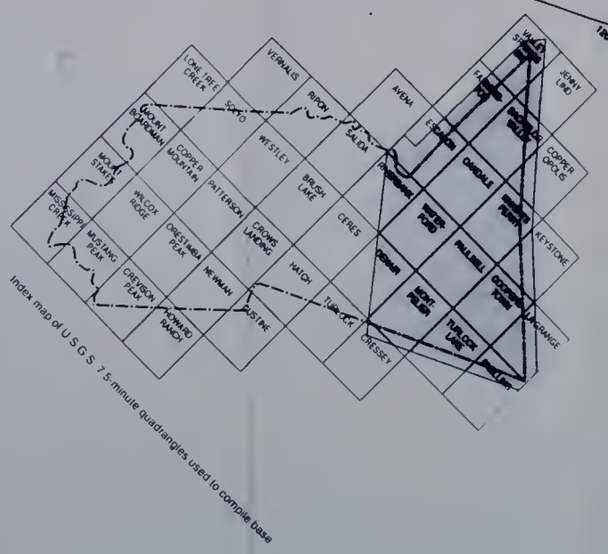
3a i(K1)

3b i(St1)

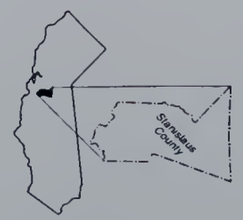
3a i(K,S,St2)

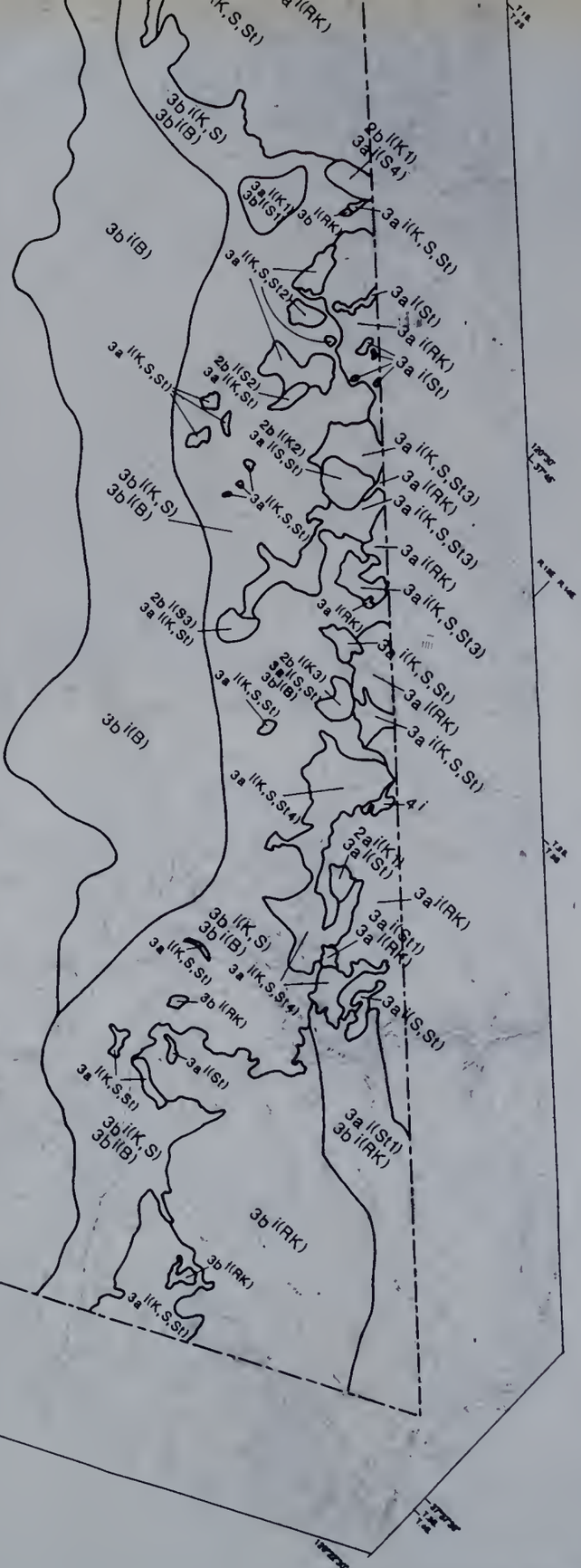
4 i

Topographic base by U.S. Geological Survey



Index map of U.S.G.S. 7.5-minute quadrangles used to compile base





Drafting and layout by J.A. Sullivan and E.L. Foster

DIVISION OF MINES AND GEOLOGY
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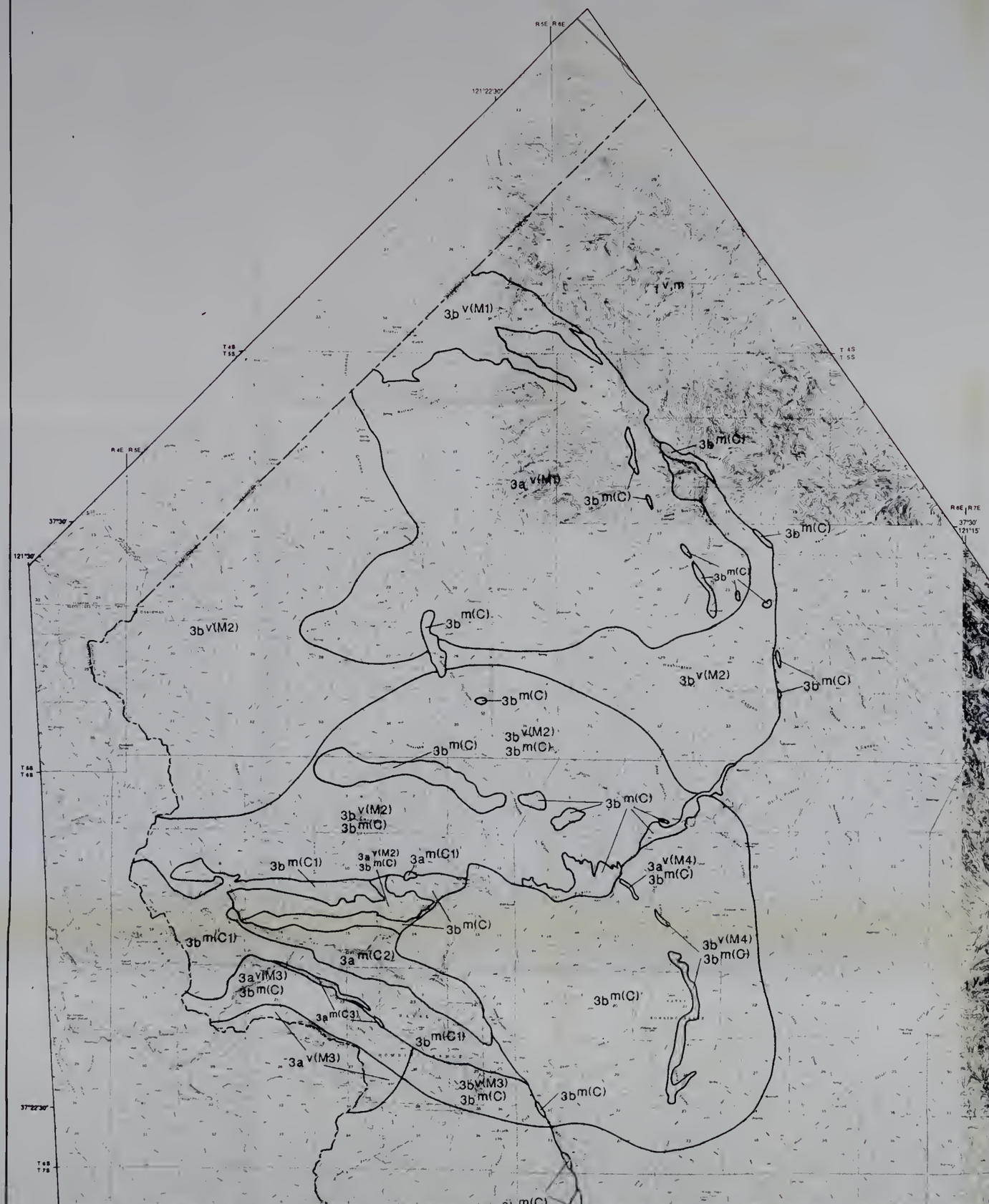
SPECIAL REPORT 173
PLATE 5
MAGMATIC SEGREGATION, VOLCANOGENIC SW

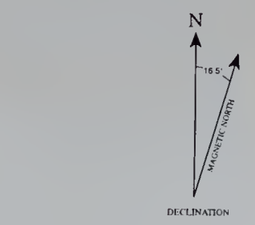
MINERAL LAND CLASSIFICATION MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for deposits formed by magmatic segregation and volcanogenic-sedimentary processes)

by
Chris T. Higgins

1993





MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources. *

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits.

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

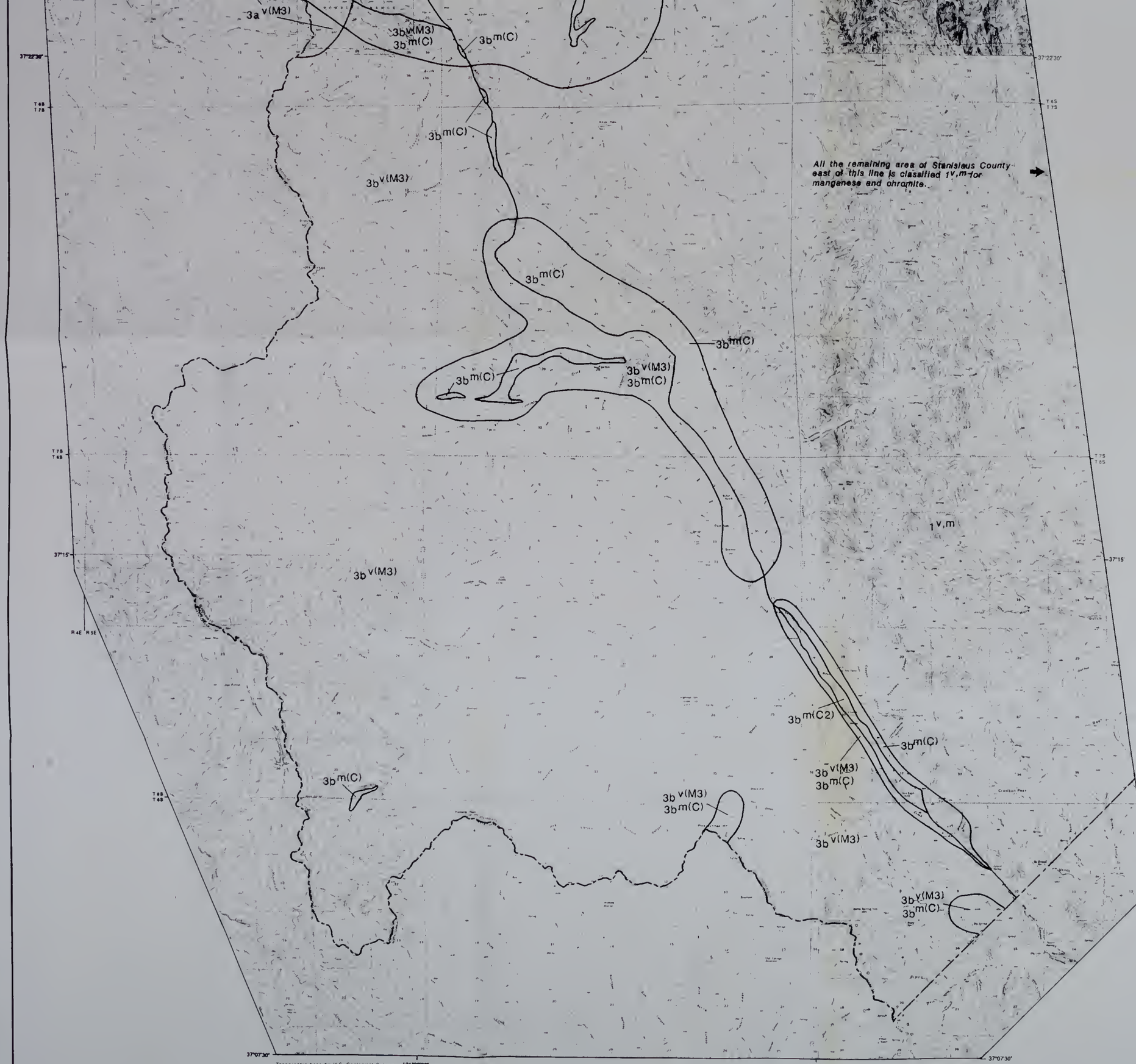
MRZ-3a: Areas containing known mineral occurrences of undetermined mineral resource significance. Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources. *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

Mineral Resource Zones are discussed in the text under the following appropriate Topic



Topographic base by U.S. Geological Survey

Drafting and layout by J.A. Sullivan and E.L. Foster

MRZ-3a: Areas of undetermined mineral resource significance. Land classified MRZ-3a represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories

Mineral Resource Zones are discussed in the text under the following **superscripts**. Those **superscripts** with **numbers** (shown on the map) refer to unique areas with particular mineral resource characteristics specifically described in the text. Those without numbers refer to areas with mineral resource characteristics described in a general way in the text.

m(C#): Areas classified for deposits formed by magmatic segregation (chromite).

v(M#): Areas classified for deposits formed by volcanogenic-sedimentary processes (manganese)

v,m: Areas classified for deposits formed by volcanogenic-sedimentary (manganese) and magmatic segregation (chromite) processes in general.

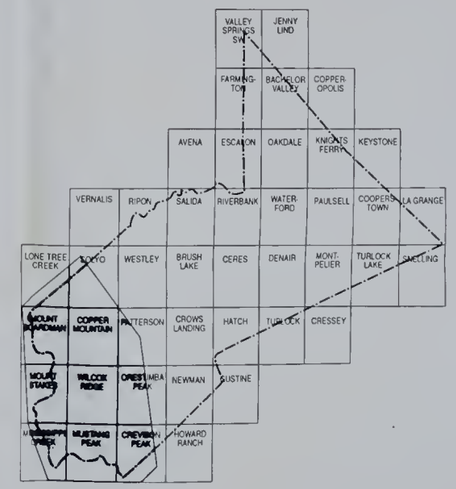
SYMBOLS

Mineral Resource Zone boundary

County line

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James L. Davis
STATE GEOLOGIST



Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA · PETE WILSON, GOVERNOR
THE RESOURCES AGENCY · DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION · EDWARD G. HEIDIG, DIRECTOR

TN24
C3
A33
no. 173
plate 6
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Sci Lib

SPECIAL REPORT 173
PLATE 6
HYDROTHERMAL SW

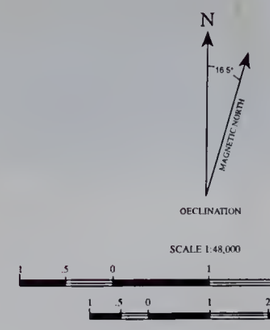
MINERAL LAND CLASSIFICATION MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for deposits formed by epigenetic hydrothermal processes)

by

Chris T. Higgins

1993



MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources. *

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Arees containing known mineral occurrences of undetermined mineral resource significance Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineret deposits Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources. *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

3b h(M1)

3a h(M5)

1h

All the remaining area of Stanislaus County east of this line is classified 1h for epithermal hydrothermal deposits containing mercury and gold.

3b h(M1)

1h

3b h(M1)

3b h(M1)

3b h(M1)

T.6S. T.7S.

T.7S. T.6S.

37°15'

37°07'30"

R.6E. R.5E.

R.5E. R.4E.

R.4E. R.3E.

121°22'30"

121°15'

Topographic base by U.S. Geological Survey

Drafting and layout by J.A. Sullivan and E.L. Foster

MRZ-4 Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources. *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

Mineral Resource Zones are discussed in the text under the following **superscripts**. Those **superscripts** with **numbers** (shown on the map) refer to unique areas with particular mineral resource characteristics specifically described in the text. Those without numbers refer to areas with mineral resource characteristics described in a general way in the text.

h(M#): Areas classified for deposits formed by epigenetic hydrothermal processes (mercury, gold).

h: Areas classified for deposits formed by epigenetic hydrothermal processes in general.

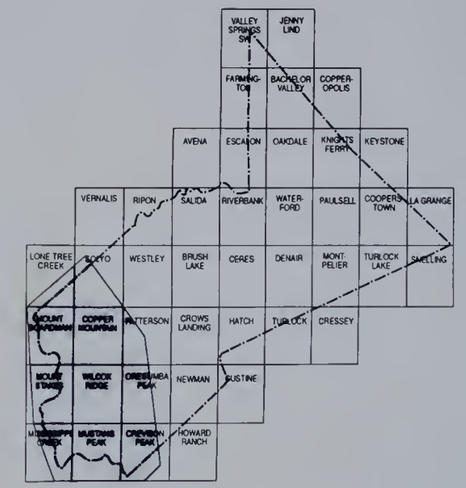
PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James L. Clarke
STATE GEOLOGIST

SYMBOLS

Mineral Resource Zone boundary

County line



Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

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TN24
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A33
no. 173
plate 7
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SPECIAL REPORT 173
PLATE 7
VOLCANOGENIC/HYDROTHERMAL NE

MINERAL LAND CLASSIFICATION MAP OF NORTHEASTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified for deposits formed by volcanogenic and hydrothermal processes)

by
Chris T. Higgins

1993

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-1: Areas where available geologic information indicates there is little likelihood for the presence of significant mineral resources *

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits.

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

MRZ-3a: Areas containing known mineral occurrences of undetermined mineral resource significance. Further exploration work within these areas could result in the reclassification of specific localities into MRZ-2a or MRZ-2b categories.

MRZ-3b: Areas containing inferred mineral occurrences of undetermined mineral resource significance. Land classified MRZ-3b represents areas in geologic settings that appear to be favorable environments for the occurrence of specific mineral deposits. Further exploration work could result in the reclassification of all or part of these areas into the MRZ-3a category or specific localities into the MRZ-2a or MRZ-2b categories.

MRZ-4: Areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources *

* The distinction between the MRZ-1 and MRZ-4 categories is important for land use considerations. **It must be emphasized that MRZ-4 classification does not imply that there is little likelihood for the presence of mineral resources, but rather there is a lack of knowledge regarding mineral occurrence.** Further exploration work could well result in the reclassification of land in MRZ-4 areas to MRZ-3 or MRZ-2 categories.

Mineral Resource Zones are discussed in the text under the following **superscripts**. Those **superscripts** with **numbers** (shown on the map) refer to unique areas with particular mineral resource characteristics specifically described in the text. Those without numbers refer to areas with mineral resource characteristics described in a general way in the text.

v(BP#): Areas classified for deposits formed by volcanogenic processes (base and precious metals, including copper, zinc, lead, gold, and silver).

h(G#): Areas classified for deposits formed by epigenetic hydrothermal processes (gold, silver).

v,h: Areas classified for deposits formed by volcanogenic and epigenetic hydrothermal processes in general.

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

James F. Davis
STATE GEOLOGIST

SCALE 1:48,000

1 0 1 2 3 Miles
1 0 1 2 3 Kilometers

SYMBOLS

Mineral Resource Zone boundary
County line

1 v,h

1 v,h

1 v,h

All the remaining area of Stanislaus County west of this line is classified 1 v,h for volcanogenic deposits containing base and precious metals and mesothermal hydrothermal deposits containing gold and silver.

3b v(BP)
3b h(G2)

3a v(BP1)
3b h(G1)

3a v(BP1)
3b h(G1)

3b v(BP)
3b h(G2)

3a v(BP1)
3b h(G1)

3a v(BP1)
3b h(G1)

37°45'

120°45'

37°37'30"

120°37'30"

37°30'

120°30'

T.5 S.
T.6 S.

R.11 E.

R.12 E.

3a v(BP1)
3b h(G1)

3b v(BP)
3b h(G2)

1 V.h

Topography base by U.S. Geological Survey

Drafting and layout by J.A. Sullivan and E.L. Foster

Stanislaus County

Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

is line
ng base
al deposits

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INDEX OF MINES AND PROSPECTS

MAP NO.	MINE NAME
1.	Liberty Mine
2.	Morsn Brothers Mine
3.	Mine (name unknown)
4	Sulphur Gulch Prospect
5.	Buckeye Mine (north workings)
6.	Buckeye Mine (south workings)
7.	Tip Top Mine
8.	Mezzera Mine
9.	Grummett-Knox Mine
10	Sunbeam Mine
11	Grummett Mine
12.	Brinkenhoffer Mine
13.	Mine (name unknown)
14.	Zacharias Road North Pit (Lee White)
15	Zacharias Road South Pit (Lee White)
16.	Del Puerto Creek Pit
17.	Prospect
18.	Section 23 Mine
19.	Crocker-Winship(?) Prospect
20.	Newhall(?) Prospect
21.	Prospect
22	Prospect
23.	Red Mountain Mine
24	Red Mountain Mine (upper tunnel)
25	Red Mountain Mine
26	Red Mountain Mine (lower tunnel)
27	Prospect
28	Black Bart Mine
29	Prospect
30.	East Black Bart Mine
31.	Prospect
32	Lookout Prospect
33	Claim 14 Prospect
34	Black Mike Prospect
35	Chrome Camp Mine
36	Phoenix Mine
37	Murmac Mine
38	Park Mine
39	Prospect
40	Black Bolt Prospect
41	Prospect
42	Mary Lou Prospect
43	Prospect
44	Prospect
45	Lucky Girl Mine
46	Prospect
47	Prospect
48	Prospect
49	Black Bear Mine
50.	Prospect
51.	No.5 Mine
52	No.5 Mine (main workings)
53.	No.5 Mine
54	No.5 Mine
55.	No.5 Mine
56.	Prospect
57.	Prospect
58.	Prospect
59	Prospect
60	Prospect
61	Prospect
62	Prospect
63.	Adobe Canyon Mine (main workings)
64	Adobe Canyon Mine (east workings)
65.	Prospect
66	Prospect
67	Prospect
68.	Adobe Valley Mine (main workings)
69	Adobe Valley Mine
70.	Gerber Mine
71	Winegar Prospect
72	Prospect
73.	Hammond(?) Prospect
74	Megnesia Camp Prospect
75	Prospect
76	Promberger Prospect
77	Hemmond Mine
78	Prospect
79	Orestimba Mine
80.	Internabonal Mine
81	Base Materials Pit
82	Muddox Pit
83	Muddox Pit
84	Muddox Pit
85	Muddox Pit
86	Muddox Pit
87.	Muddox Pit
88.	Cro-Diatomite Pit
89.	Cro-Diatomite Pit
90	Orestimba Creek Pit (Marks)
91	Stuhr Road Pit (Marks)
92	Orestimba Creek Pit (J C Scanlon)
93	Orestimba Creek Pit (T Francisco)
94	Prospect
95	Prospect
96	Bald Eagle Mine (northwest workings)
97	Bald Eagle Mine (onginal workings)
98.	Bald Eagle Mine (Howard Cattle Co)
99	Garzes Creek Pit (County of Merced)

SYMBOLS FOR MINES AND PROSPECTS

- ◇ Chromite
- ▽ Diatomite
- ▲ Magnesite
- □ Manganese
- ○ Mercury
- ◭ Quartz (silica)
- ○ Sand and Gravel (active in 1993) Locations of symbols are generalized
- ⊕ Sand and Gravel (inactive in 1993) Locations of symbols are generalized
- X Commodity unknown

All mines end prospects with index numbers are listed in Appendix A of Special Report 173 Those without index numbers are outside the county in areas not classified for mineral resource zones

- 11 (3) Location of mine or prospect, which is also site of sampling for geochemical analysis Circled numbers are keyed to geochemical analyses presented in Appendix B of Special Report 173
- (14) Location of site of sampling for geochemical analysis Circled numbers are keyed to geochemical analyses presented in Appendix B of Special Report 173

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols.

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a

Specific Mineral Resource Zones are discussed in the text under the following superscripts:

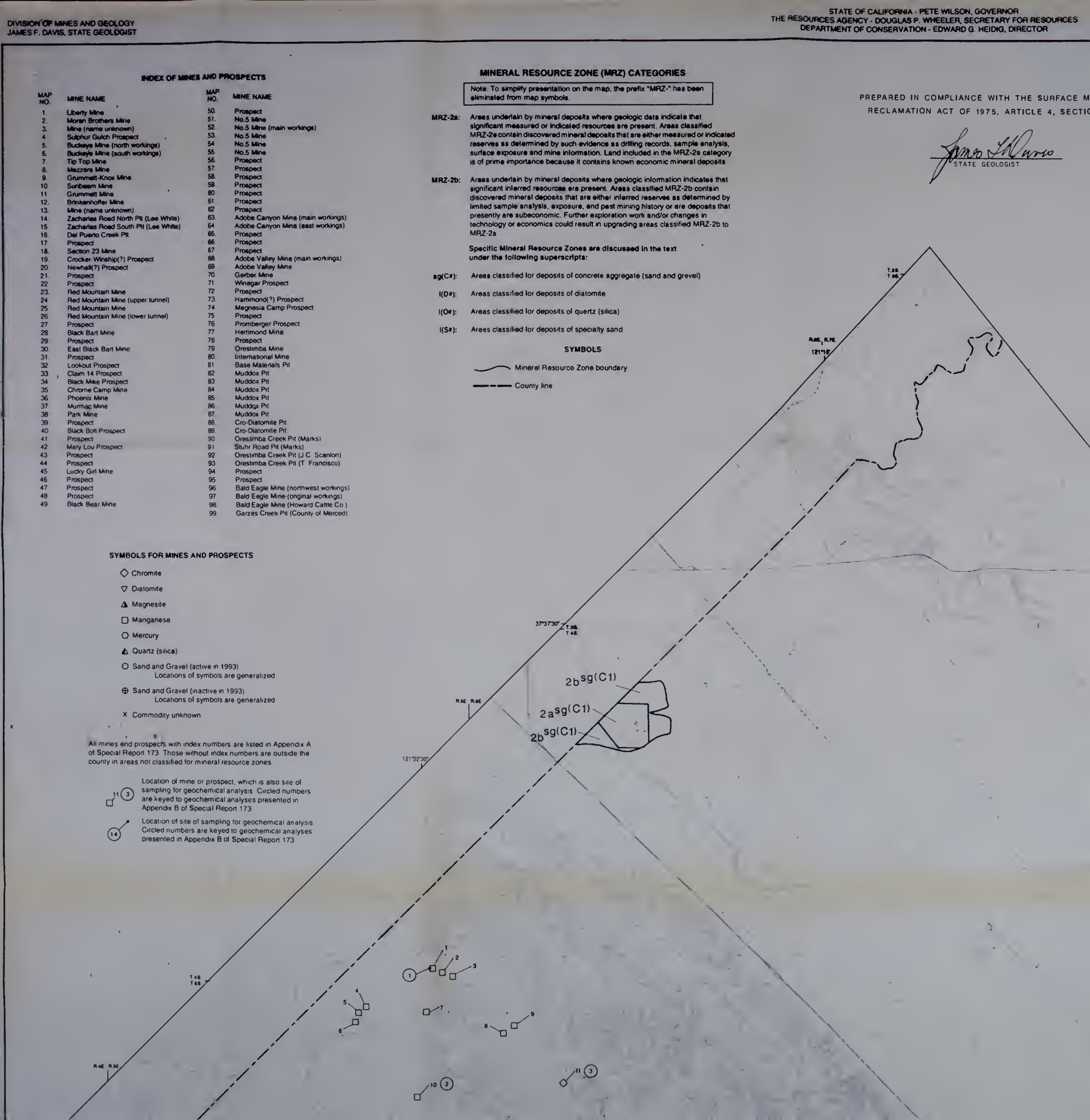
- **sg(C#):** Areas classified for deposits of concrete aggregate (sand and grevel)
- **I(D#):** Areas classified for deposits of diatomite
- **I(O#):** Areas classified for deposits of quertz (silica)
- **I(S#):** Arees classified for deposits of specialty sand

SYMBOLS

- Mineral Resource Zone boundary
- County line

PREPARED IN COMPLIANCE WITH THE SURFACE M
RECLAMATION ACT OF 1975, ARTICLE 4, SECTIO

James F. Davis
STATE GEOLOGIST



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no. 173
plate 8A
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MINERAL LAND CLASSIFICATION MAP OF SOUTHWESTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified as MRZ-2a or MRZ-2b for all mineral deposits, with locations of mines, prospects, and sites of geochemical analysis)

by

Chris T. Higgins and Don L. Dupras

1993

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

STATE GEOLOGIST

SCALE 1:48,000

1 0 1 2 3 Miles

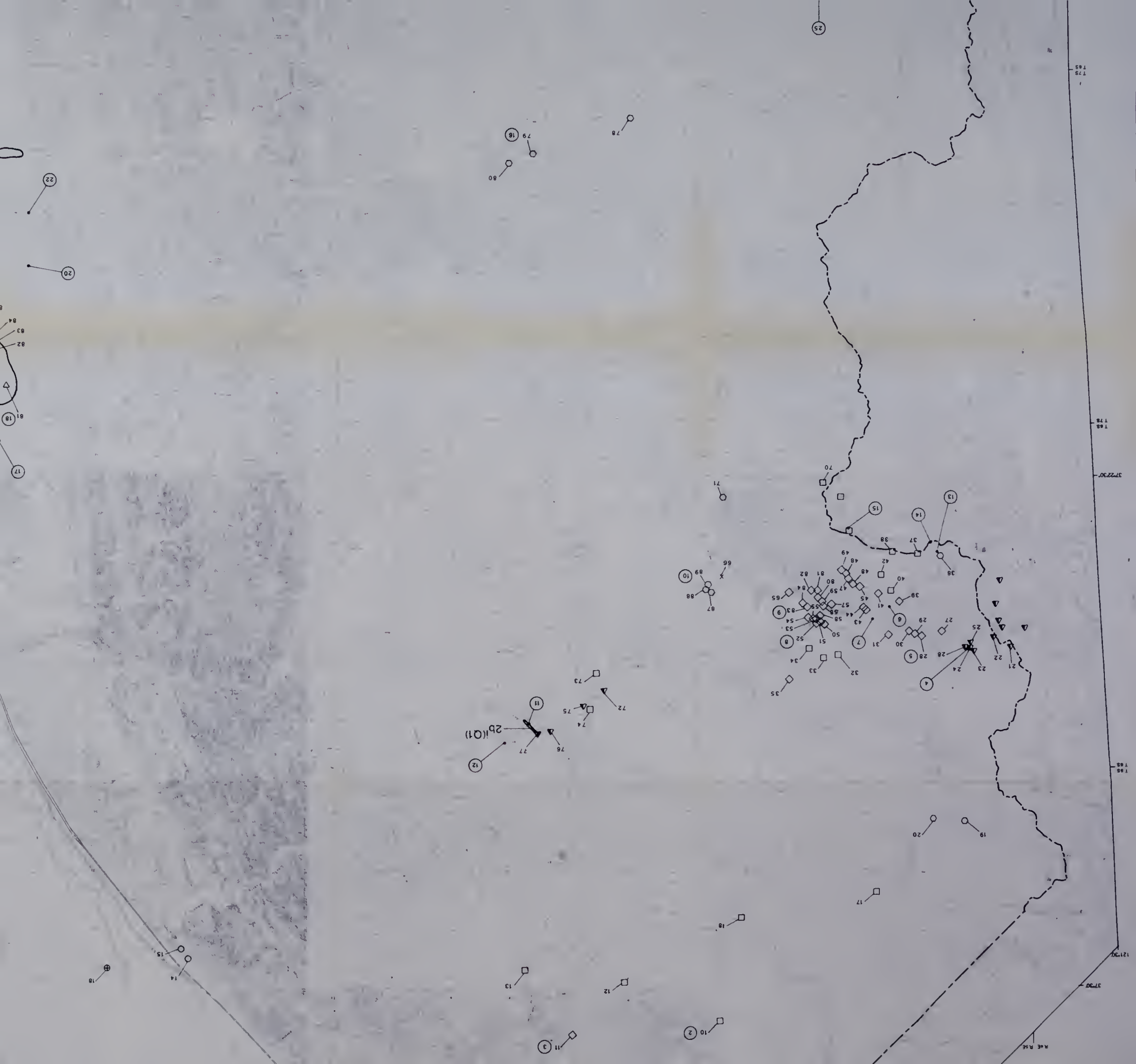
1 0 1 2 3 Kilometers

N

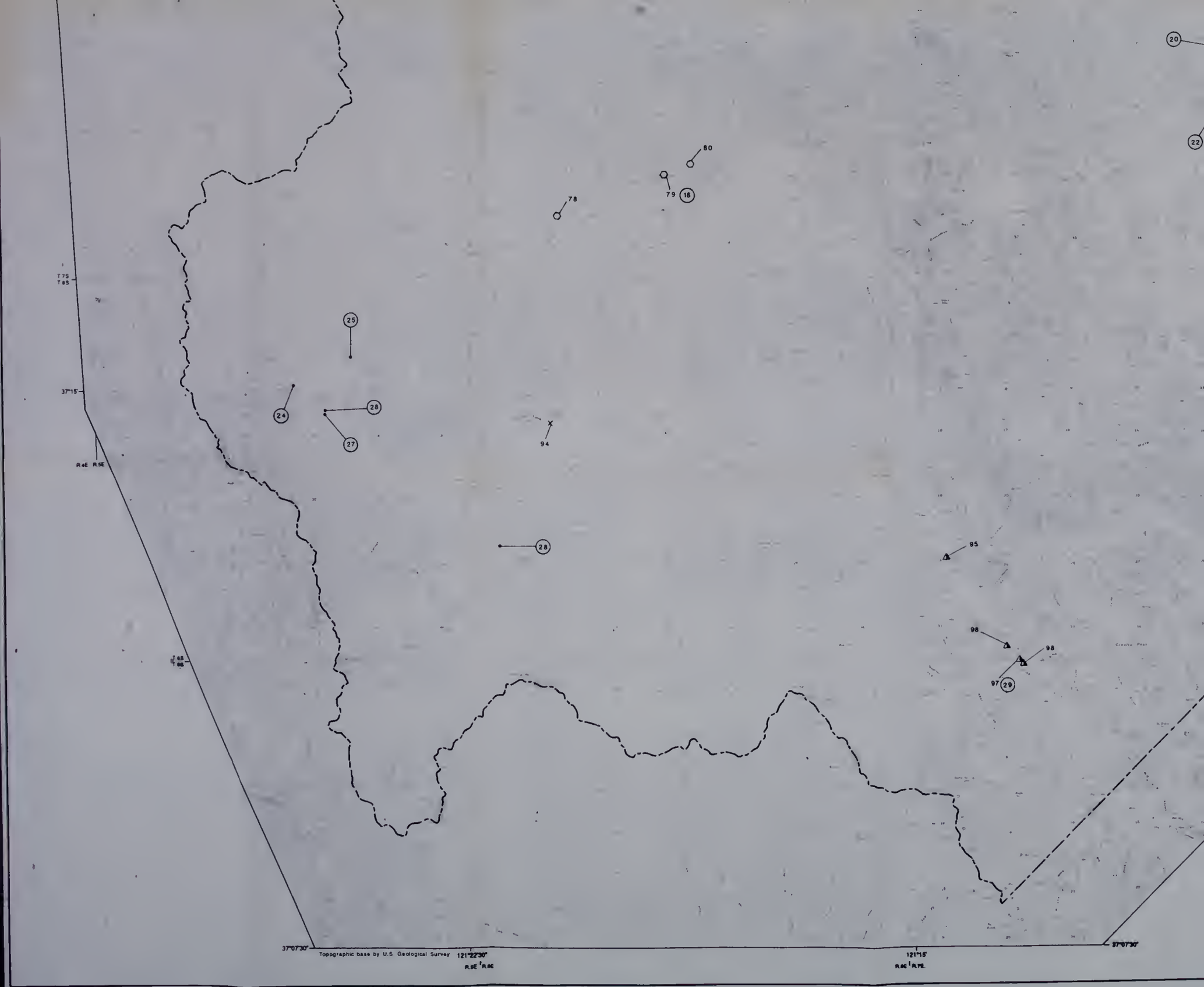
16.5

MAGNETIC NORTH

DECLINATION



121°00'
37°30'
T 6S
T 7S
37°22'30"
121°00'
37°15'
R.9E
R.10E
14
15
16
17
18
19
20
21
22
23
81
82
83
84
85
86
87
88
89
90
91
92
93
99
$2b^{i(D1)}$
$2b^{sg(C2)}$
$2a^{sg(C2)}$
$2b^{sg(C2)}$
$2b^{i(S1)}$


T7S
T8S
37°15'
R4E R5E
T8S
T9S
37°07'30"
121°22'30"
R5E R6E
121°15'
R5E R6E
37°07'30"
Topographic base by U.S. Geological Survey
20
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94
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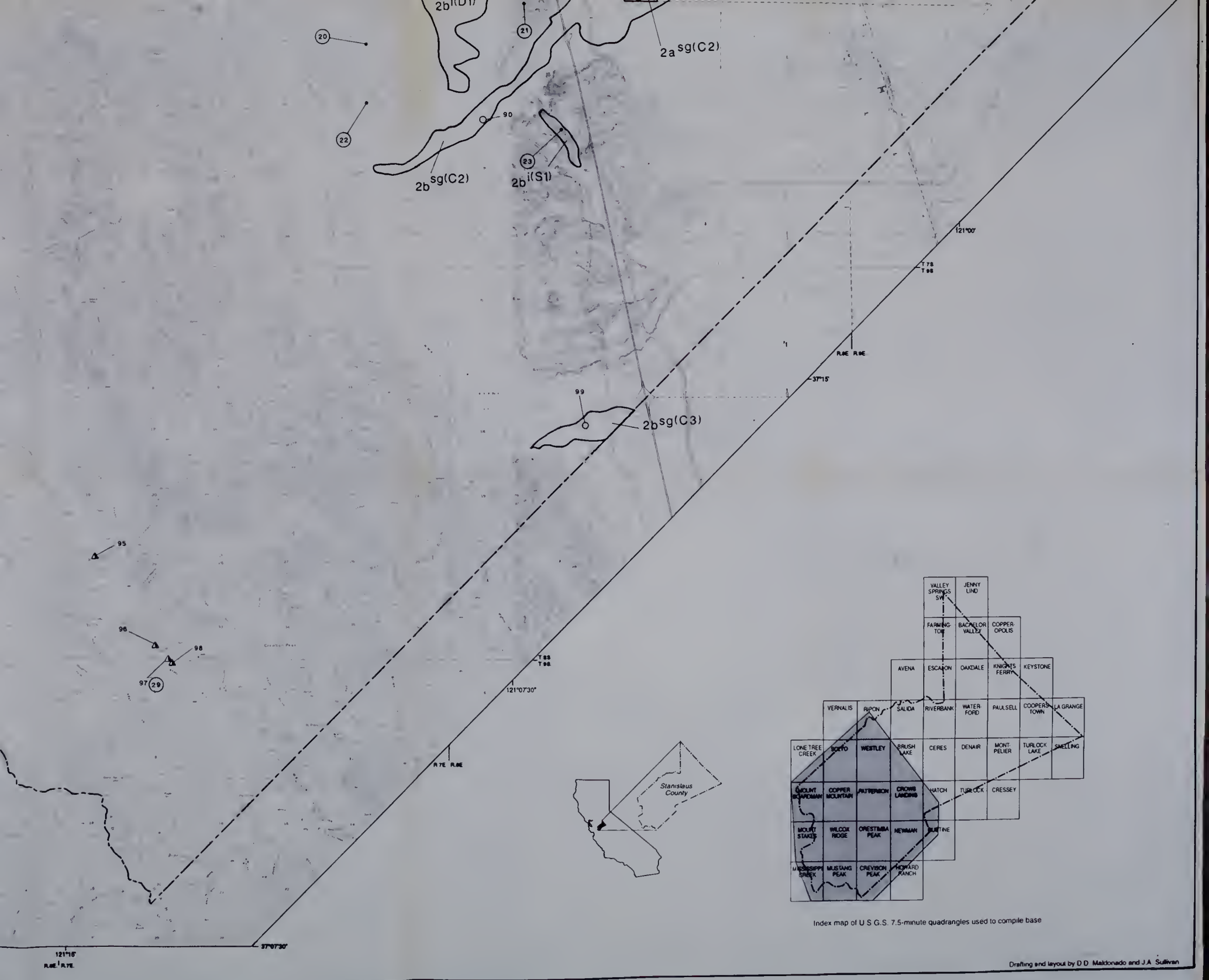
95
98
98
97
29



Index map of U S G.S. 7.5-minute quadrangles used to compile base

Drafting and layout by D D Maldonado and J A Sullivan

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C3
A33
no. 173
plate 8B
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SPECIAL REPORT 173
PLATE 8B
MRZ-2 COMPOSITE CENTRAL

MINERAL LAND CLASSIFICATION MAP OF CENTRAL STANISLAUS COUNTY, CALIFORNIA

(Areas classified as MRZ-2a or MRZ-2b for all mineral deposits, with locations of mines and prospects)

by

Chris T. Higgins and Don L. Dupras

1993

INDEX OF MINES AND PROSPECTS

MAP NO.	MINE NAME
100	Ripon Pit (Modesto Sand and Gravel)
101	Hatch Road Pit (Standard Materials)
102	Bonzi Pit (Rudy Bonzi)
103	Hatch Road Pit (Putnam)
104	Greystone Block Company Pit (Greystone Block)
105	Dry Creek Pit (Teichert)

SYMBOLS FOR MINES AND PROSPECTS

○ Sand and Gravel (active in 1993)
Locations of symbols are generalized.

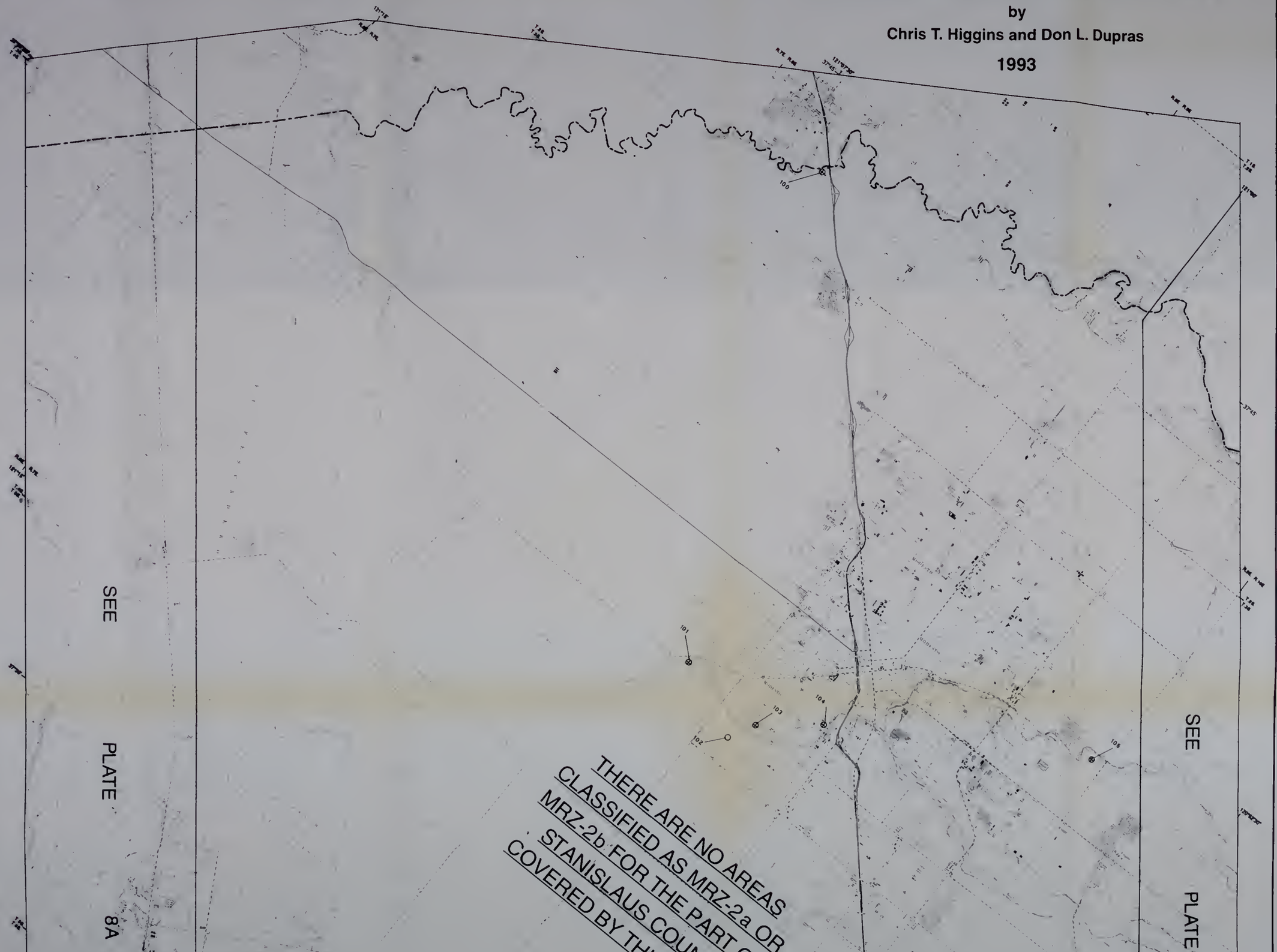
⊕ Sand and Gravel (inactive in 1993)
Locations of symbols are generalized.

All mines and prospects with index numbers are listed in Appendix A of Special Report 173.

SYMBOLS

Mineral Resource Zone boundary

County line



8A

8C

PLATE

AREA OF MRZ-2a OR MRZ-2b AREAS

AREA OF THE PART OF STANISLAUS COUNTY

COVERED BY THIS PLATE

Topographic base by U S Geological Survey

Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

Stanislaus County

VERNALIS, RIPON, AVENA, ESCALON, MANTECA, LONE TREE CREEK, SCHULTE, GRAYSON, WATERFORD, KNIGHTS FERRY, KEYSTONE, MOUNT BEATRICHAN, COPPER MOUNTAIN, PATTERSON, GANDALF, BALLICO VALLEY, COPPER CROSS, MOUNTAIN HOUSE, WILCOX RIDGE, CROWS LANDING, NEWMAN, DENAIR, PALMSEL, COOPERSTOWN, LA GRANGE, MUSTANG PEAK, ORESTIMBA PEAK, CRESSEY, TURLOCK LAKE, MERCED FALLS, CREVISON PEAK, HOWARD RANCH, MONTPELIER, SHILOH, MISSISSIPPI CREEK, SCOTT, HICKMAN, KNIGHTS FERRY, VALLEY SPRINGS SW, JENNY LIND, FARMINGTON, BALLICO VALLEY, COPPER CROSS, GANDALF, WATERFORD, PALMSEL, COOPERSTOWN, LA GRANGE, MONTPELIER, TURLOCK LAKE, MERCED FALLS

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importence because it contains known economic mineral deposits

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

STATE GEOLOGIST

N

15.5°

MAGNETIC NORTH

DECLINATION

SCALE 1:48,000

1.5 0 1 2 3 Miles

1.5 0 1 2 3 Kilometers

Drafting and layout by D D Maldonado and J A Sullivan

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA - PETE WILSON, GOVERNOR
THE RESOURCES AGENCY - DOUGLAS P. WHEELER, SECRETARY FOR RESOURCES
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SPECIAL REPORT 173
PLATE 8C
MRZ-2 COMPOSITE, MINES, GEOCHEMISTRY NE

MINERAL LAND CLASSIFICATION MAP OF NORTHEASTERN STANISLAUS COUNTY, CALIFORNIA

(Areas classified as MRZ-2a or MRZ-2b for all mineral deposits, with locations of mines, prospects, and sites of geochemical analysis)

by

Chris T. Higgins and Don L. Dupras

1993

SCALE 1:48,000

1 .5 0 1 2 3 Miles

1 .5 0 1 2 3 Kilometers

MINERAL RESOURCE ZONE (MRZ) CATEGORIES

Note: To simplify presentation on the map, the prefix "MRZ-" has been eliminated from map symbols

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant measured or indicated resources are present. Areas classified MRZ-2a contain discovered mineral deposits that are either measured or indicated reserves as determined by such evidence as drilling records, sample analysis, surface exposure and mine information. Land included in the MRZ-2a category is of prime importance because it contains known economic mineral deposits

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant inferred resources are present. Areas classified MRZ-2b contain discovered mineral deposits that are either inferred reserves as determined by limited sample analysis, exposure, and past mining history or are deposits that presently are subeconomic. Further exploration work and/or changes in technology or economics could result in upgrading areas classified MRZ-2b to MRZ-2a.

Specific Mineral Resource Zones are discussed in the text under the following superscripts:

sg(C#): Areas classified for deposits of concrete aggregate (sand and gravel)

l(K#): Areas classified for deposits of sedimentary kaolinitic clay

l(S#): Areas classified for deposits of specialty sand

SYMBOLS

- Mineral Resource Zone boundary
- County line

SYMBOLS FOR MINES AND PROSPECTS

- △ Clay
- ◈ Copper
- ⊛ Gold (placer)
  Generally hydraulic. Locations of symbols are generalized. See geologic map for extent of tailings
- ⊡ Gold ± silver and/or platinum (placer).
  Dredging. Locations of symbols are generalized. See geologic map for extent of tailings
- ▼ Mineral Pigment (ochre)
- ○ Sand and Gravel (active in 1993)
  Locations of symbols are generalized.
- ⊕ Sand and Gravel (inactive in 1993)
  Locations of symbols are generalized.
- ◑ Stone (dimension)
- × Commodity unknown

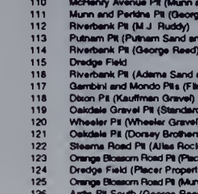
All mines and prospects with index numbers are listed in Appendix A of Special Report 173. Those without index numbers are outside the county in areas not classified for mineral resource zones.

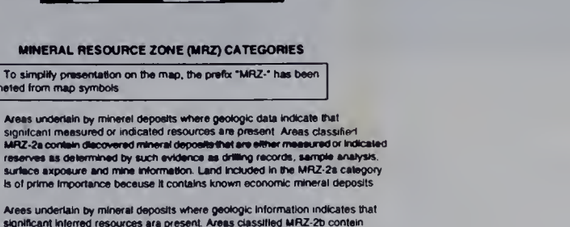
161 (35) Location of mine or prospect, which is also site of sampling for geochemical analysis. Circled numbers are keyed to geochemical analyses presented in Appendix B of Special Report 173

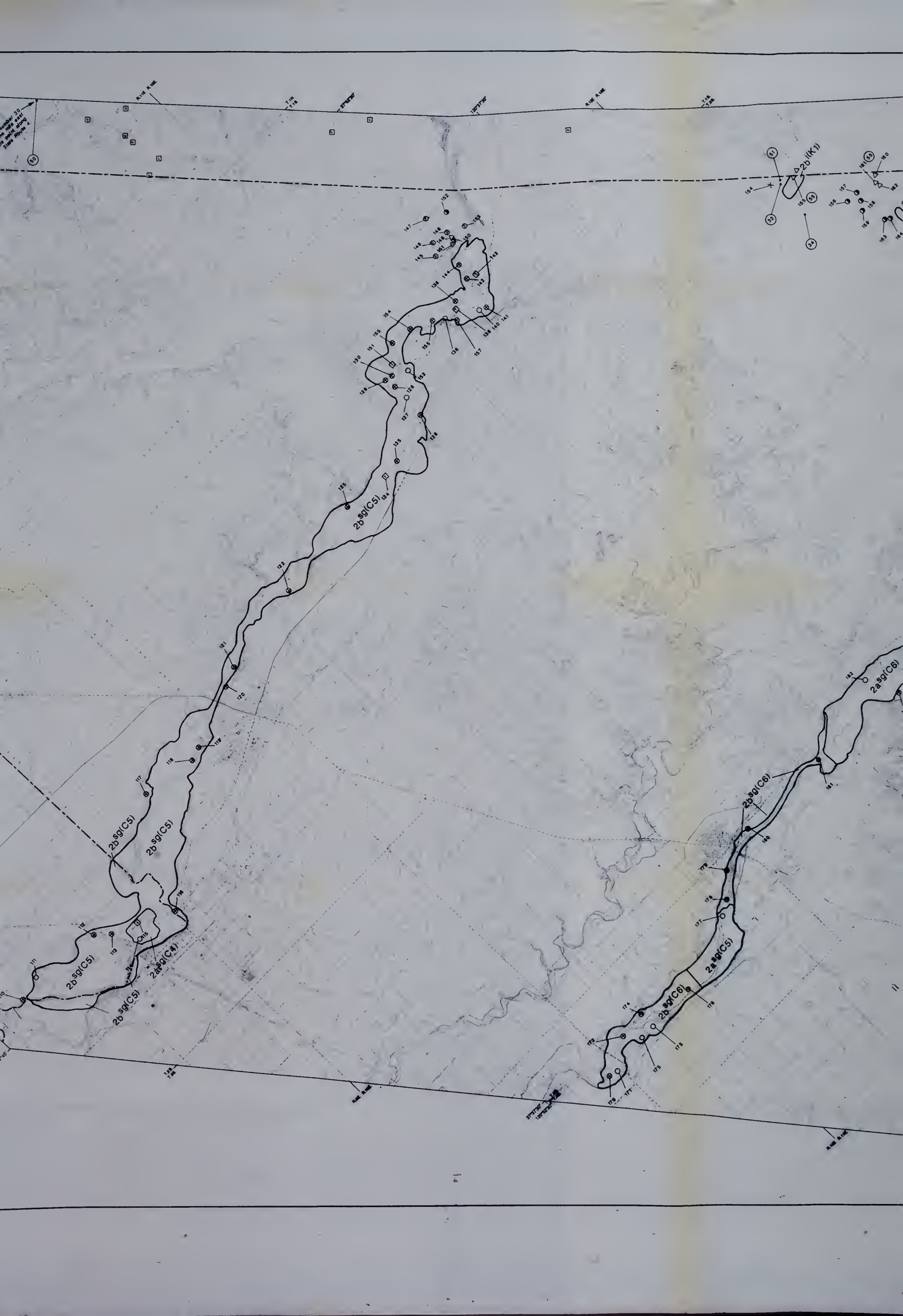
(34) Location of site of sampling for geochemical analysis. Circled numbers are keyed to geochemical analyses presented in Appendix B of Special Report 173.

INDEX OF MINES AND PROSPECTS

MAP NO.	MINE NAME
106	Dredge Field (California Gold Dredging)
107	Dredge Field
108	Dunton Road Site (Landlord and Ripley)
109	Shirley Creek Site (Brichetto Ranch)
110	McHenry Avenue Pit (Munn and Perkins)
111	Munn and Perkins Pit (George Reed)
112	Riverbank Pit (M.J. Ruddy)
113	Putnam Pit (Putnam Sand and Gravel)
114	Riverbank Pit (George Reed)
115	Dredge Field
116	Riverbank Pit (Adams Sand and Gravel)
117	Gambini and Mondo Pits (Flintkote)
118	Dixon Pit (Kauffman Gravel)
119	Oakdale Gravel Pit (Standard Rock)
120	Wheeler Pit (Wheeler Gravel)
121	Oakdale Pit (Dorsey Brothers)
122	Stearns Road Pit (Atlas Rock)
123	Orange Blossom Road Pit (Placer Properties)
124	Dredge Field (Placer Properties)
125	Orange Blossom Road Pit (Munn and Perkins)
126	Ardis Pit South (George Reed)
127	Ardis Pit North (George Reed)
128	Horseshoe Bar Pit (Flintkote)
129	Edwards Pit (J. & K. Edwards)
130	Rodden Road Pit (Munn and Perkins)
131	Dredge Field (Placer Properties?)
132	Hodge Ranch Pit (George Reed)
133	Lancaster Road Pit (Wilkins)
134	Wilkins Upper Pit (Wilkins)
135	Frymire Road Pit (Western Sand and Gravel)
136	Ohe Pit (Karl Ohe)
137	Wildcat Creek Pit (Karl Ohe)
138	Dredge Field (Yankee Hill Gold Dredging)
139	Frymire Road Pit (Oakdale Concrete and Pipe)
140	Wilkins Ranch Pit (Karl Ohe)
141	Rifle Pit (Frank Alegre)
142	Gnesner Pit (Elmer Wendt)
143	Dredge Field
144	Knights Ferry Pit (Madonna Construction)
145	Placer Mine (name unknown)
146	Placer Mine (name unknown)
147	Placer Mine (name unknown)
148	Placer Mine (name unknown)
149	Winkler Pit
150	Mine (name unknown)
151	Mine (name unknown)
152	Wright Ranch(?) Quarry
153	Placer Mine (name unknown)
154	Prospect
155	49er Pit
156	Quarry (name unknown)
157	Quarry (name unknown)
158	Quarry (name unknown)
159	Quarry (name unknown)
160	Cooperstown Pit
161	Cooperstown Pit
162	Cooperstown Pit
163	Quarry (name unknown)
164	Quarry (name unknown)
165	Curtoni Pit
166	Curtoni Pit
167	Curtoni Pit
168	Curtoni Pit
169	Curtoni Pit
170	Schmidt Pit (Flintkote)
171	Schmidt Pit (Western Stone)
172	Aldrich Road Pit (Flintkote)
173	Landmark Pit (Western Stone)
174	Tuolumne River Pit (American Sand and Gravel)
175	Warner Pit (Western Stone)
176	Tuolumne River Pit (Santa Fe Rock)
177	Hickman Pit (Western Stone)
178	Waterford Pit (Putnam Sand and Gravel)
179	Waterford Pit (Sikova and Wychopean)
180	Bearden Pit (M.J. Ruddy)
181	Waterford Pit (George Reed)
182	Waterford Pit (M.J. Ruddy)
183	Warner Sand Pit (H. & J. Warner)
184	Waterford Pit (7-11 Materials)
185	Dredge Field (Yuba Consolidated Gold Fields)
186	Roberts Ferry Pit (7-11 Materials)
187	La Grange Pit (M.J. Ruddy)
188	Dredge Field (La Grange Gold Dredging)
189	Cree Ranch Pit (Western Stone)
190	Dredge Field (La Grange Gold Dredging)
191	Dredge Field (La Grange Gold Dredging)
192	La Grange Pit (Flintkote)
193	Dredge Field (La Grange Gold Dredging)
194	Prospect
195	Prospect
196	Kraftile Pit
197	Quarry (name unknown)
198	Dredge Field (La Grange Gold Dredging)
199	La Grange Pit (Standard Materials)
200	La Grange Pit (County of Stanislaus)
201	Quarry (name unknown)
202	Placer Mine (name unknown)
203	Sarah Reeves Pit (George Reed)
204	Placer Mine (name unknown)
205	Placer Mine (name unknown)
206	French Pit
207	Patricksville(?) Pit
208	Dredge Field (Tuolumne Dredge)
209	Borrow Pit (Caltrans)
210	Prospect
211	Placer Mine (name unknown)






2b (K1)
2b sg(C5)
2b sg(C5)
2b sg(C5)
2b sg(C5)
2a sg(C4)
2b sg(C5)
2a sg(C6)
2b sg(C6)
2a sg(C5)
2b sg(C6)

2b sg(C6)

2a sg(C6)

2b sg(C6)

2a sg(C7)

2b sg(C6)

2a i(K1)

2b i(K1)

2b i(S2)

2b i(K2)

2b i(S3)

2b i(K3)

Topographic base by U.S. Geological Survey

Index map of U.S.G.S. 7.5-minute quadrangles used to compile base

Stanislaus County

PREPARED IN COMPLIANCE WITH THE SURFACE MINING AND RECLAMATION ACT OF 1975, ARTICLE 4, SECTION 2761

STATE GEOLOGIST

Drafting and layout by D.D. Maldonado and J.A. Sullivan

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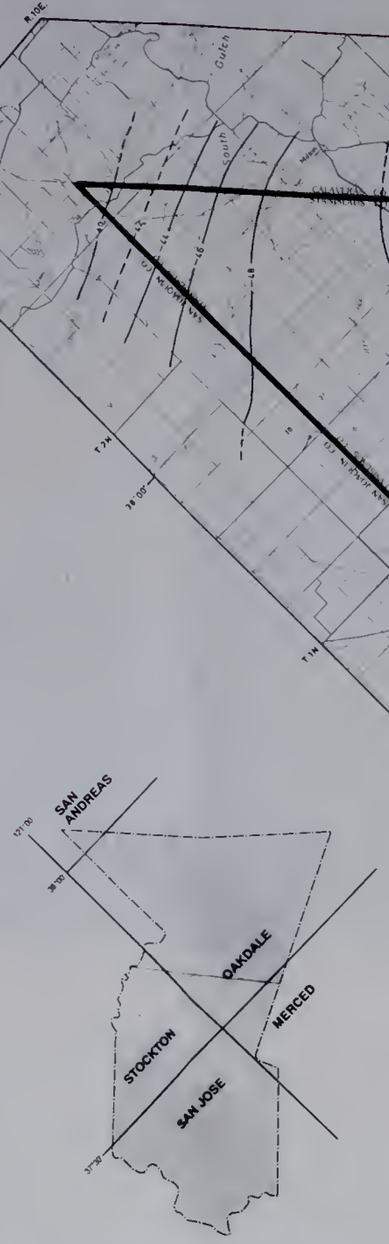
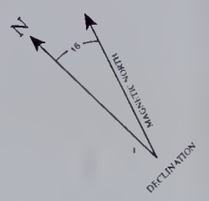
SPECIAL REPORT 173
PLATE 9
BOUGUER GRAVITY



Index map of U.S.G.S. and U.S. Bureau of Land Management 30 x 60-minute quadrangles used to compile base



BOUGUER GRAVITY MAP OF STANISLAUS COUNTY, CALIFORNIA

by

Rodger H. Chapman

1993

0 1 2 3 4 5 miles

0 1 2 3 4 5 kilometers

SCALE 1:100,000

EXPLANATION

—— Gravity contour (interval: 2 milligals)

The following apply to this map:

REDUCTION DENSITY: 2.67 g/cm^3

DATUM: 979,958.74 milligals at the U.S. Geological Survey in Menlo Park, California (Base Station No. 173 of Chapman, 1966)

REFERENCE SPHEROID: International Ellipsoid of 1930

TERRAIN CORRECTIONS: Made for all stations out to a distance of 166.7 kilometers

SOURCES OF DATA: Robbins and others (1974, 1976b), Snyder and others (1982), Andrew Griscom (U.S. Geological Survey, written communication) and this study

Drafting and layout by J.D. Williams and J.A. Sullivan

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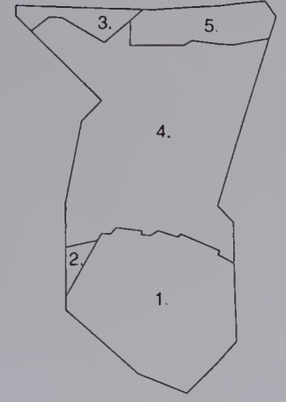
SPECIAL REPORT 173
PLATE 10
AEROMAGNETIC

AEROMAGNETIC MAP OF STANISLAUS COUNTY, CALIFORNIA

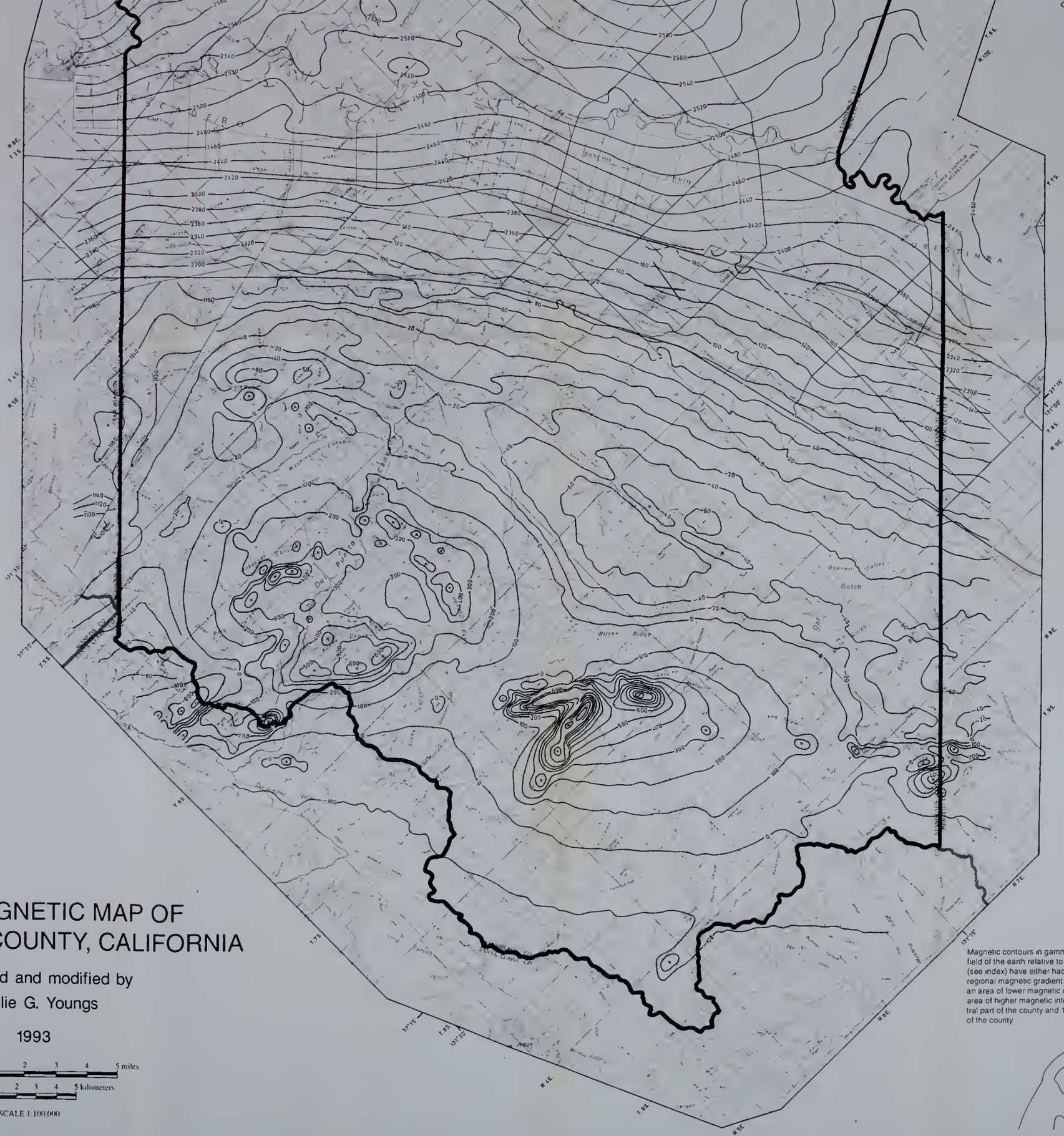
Compiled and modified by
Leslie G. Youngs

1993



INDEX OF REFERENCES USED TO COMPILE AEROMAGNETIC MAP

1 Abrams (1992)
2 Hanna and Brabb (1979)
3 Henderson and others (1966)
4 Meuschke and others (1966)
5 Ponce and Langenheim (1987)


T.6S.
R.10E.
T.7S.
R.9E.
T.5S.
R.8E.
T.8S.
R.7E.
T.9S.
R.6E.
37°30'
37°15'
121°30'
121°15'
DIVIDE
Patterson Pass
Livermore
Altamont
Pass
Tesla
Corral Hollow
Carnegie
State Vehicular Recreation Area
Del Puerto
Canyon
Orestimba
Wilson Ridge
Beaver Valley
Gustine
Quinto
Quinto Creek
Garzas Creek
Romero
Ranch
Ortigalita
Creek
Arroyo
Hospital
Creek
Grayson
Newman
Crows
Landing
Dry Creek
Valley
Hills
Ferry
Lone Tree
Canyon
Bennett
Valley
Gulch
Dry
Creek
Valley
Boyd
Canyon
Lone Tree
Canyon
Del Puerto
Canyon
Willow Water
Canyon
Hospital
Canyon
Ingram
Canyon
Orestimba
Canyon
Quinto
Canyon
Garzas
Canyon
Romero
Canyon
Arroyo
Hondo
Canyon
Arroyo
Del Puerto
Canyon
Ortigalita
Creek
Arroyo
Del Puerto
Canyon
Arroyo
Del Puerto
Canyon
Arroyo
Del Puerto
Canyon

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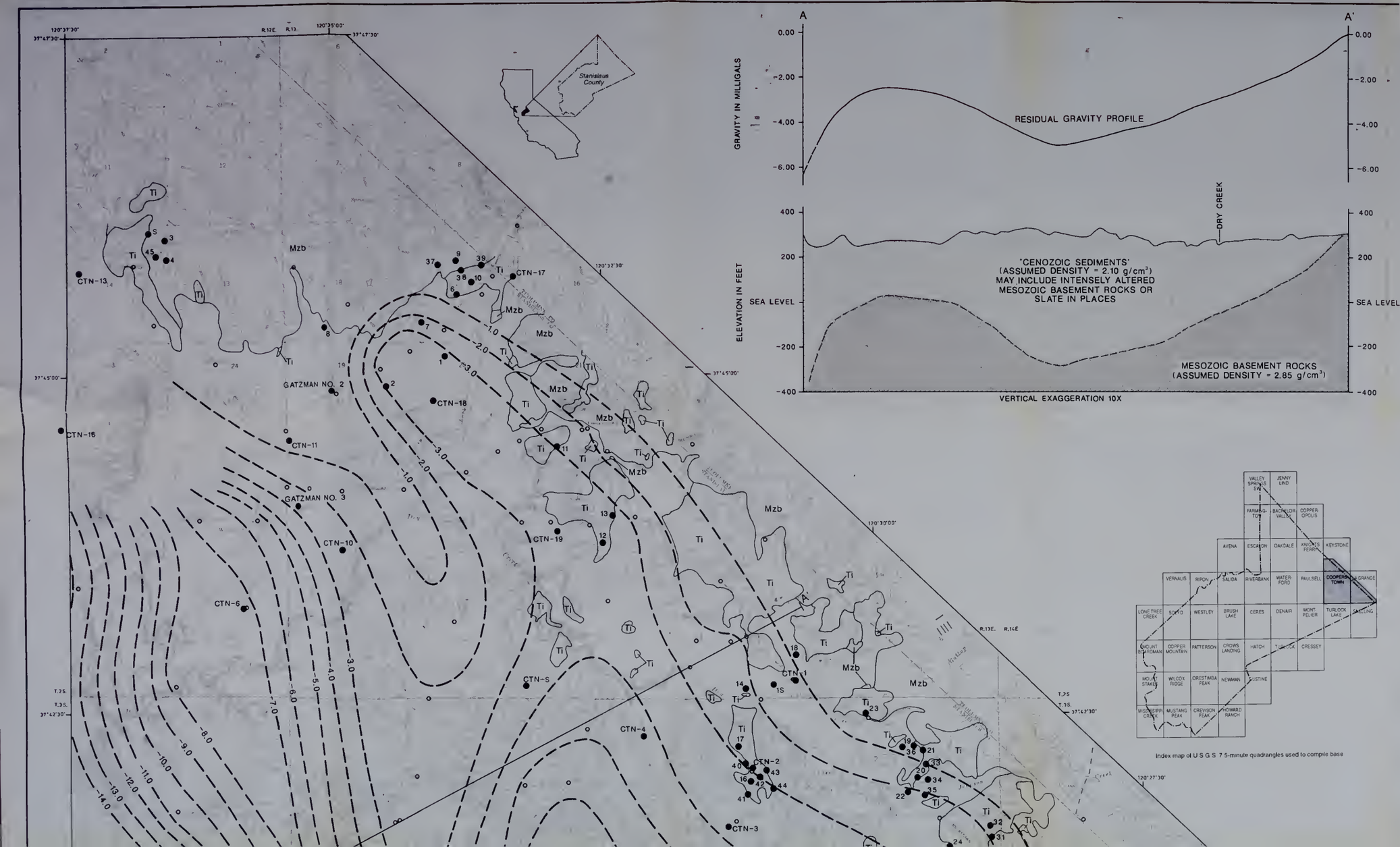
SPECIAL REPORT 173
PLATE 11
COOPERSTOWN GRAVITY

DRILL HOLES WITH REPORTED OR INTERPRETED DEPTHS TO BASEMENT

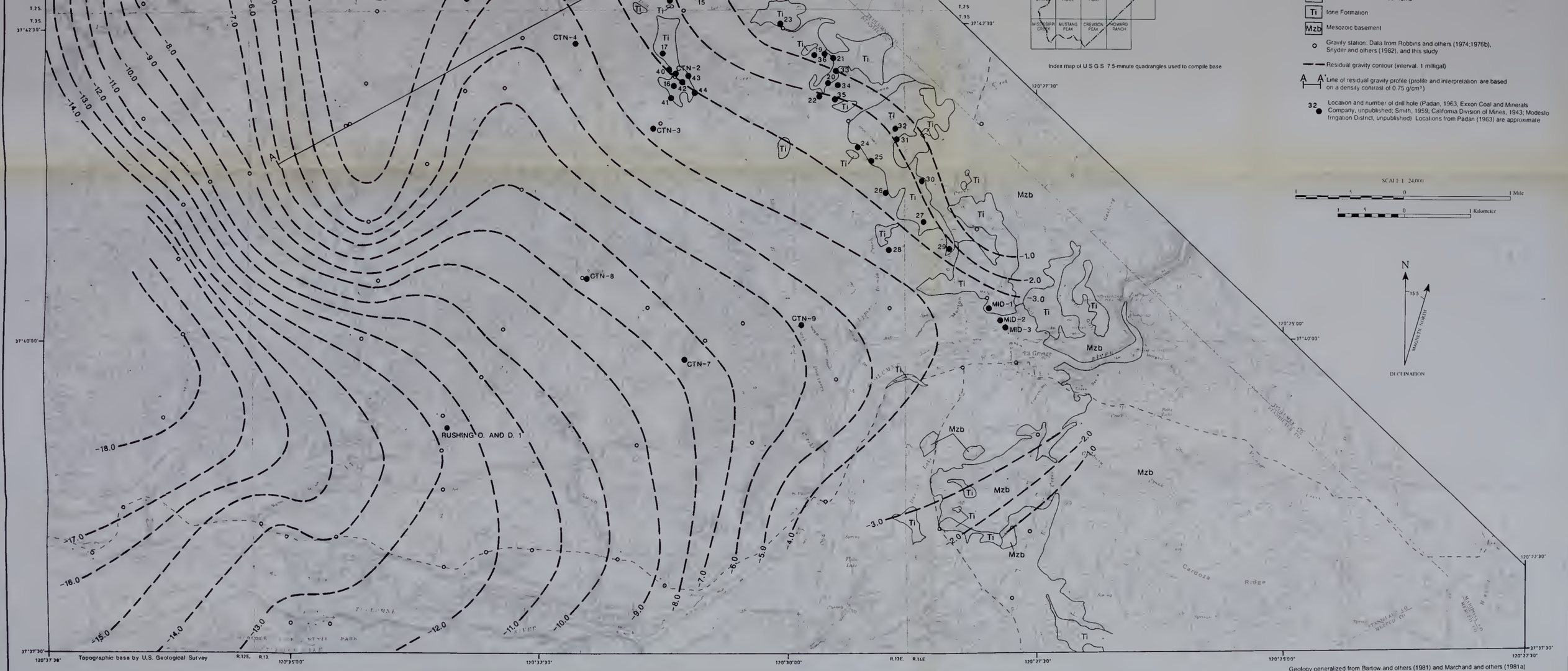
HOLE NO.	REPORTED ELEVATION (FEET)	DEPTH (FEET)	DEPTH TO BASEMENT (FEET)	INTERPRETED INTERVAL OF IONE FORMATION (FEET)	REPORTED LIGNITE
1	260	126	>186?	>76?	Yes
2	255	132	>132?	>44?	Yes?
3	305	35	12?	?	No
4	310	50	2?	0?	No
5	355	32	[illegible]	8?	No
6	295	86	[illegible]	?	No
7	270	103	94?	?	No
8	270	90	?	?	No
9	315	62	>62?	>62?	No
10	305	130	127?	127?	Yes
11	275	97	>97	>97	No
12	290	144	138?	138?	No
13	310	105	80	77	No
14	280	21	>21	>3	No
15	280	68	>68	>55	No
16	330	160	>160	>160	No
17	312	47	>47	?	No
18	285	57	>57	?	No
19	340	77	40	40?	No
20	350	92	50?	50?	No
21	360	98	>74?	>74	No
22	340	53	>53	>13	No
23	312	66	>66	>16	No
24	330	140	>140	>104	No
25	340	63	>63?	>63?	No
26	340	30	>30	0	No
27	400	102	100?	100?	No
28	330	76	>76	0?	No
29	300	97	71	71	No
30	350	47	10	10	No
31	350	72	48	48	No
32	400	2	>2	2	No
33	355	76	>78	>76	No
34	350	76	>76	72	Yes
35	360	50	>50	0	No
36	360	42	>42	>42	No
37	300	50	>5	0	No
38	315	76	>76	>76	Yes
39	300	115	>107	>107	Yes?
40	310	76	>76	0	No
41	350	76	>76	>76	No
42	350	50	>50	>50	No
43	330	60	>80	>60	No
44	335	39	>39	0?	No
45	300	105	0?	0	No
MID 1	300	140	125	122	No
MID 2	200	56	44	41	No
MID 3	180	37	37	21?	No
Gatzman No 2	250	347	347	?	?
Gatzman No 3	227	623	623	?	?
Rushing Oil & Dev No 1	240	2600	>2600?	?	No
CTN-1	286	143	120	40	No
CTN-2	320	320	275	213	No
CTN-3	325	454	410	260	No
CTN-4	275	454	450	290	No
CTN-5	294	610	600	>255	Yes
CTN-6	221	660	>660	340?	Trace
CTN-7	258	540	>540	>280?	No
CTN-8	261	580	>580	>245?	Trace
CTN-9	269	495	465	215?	Trace
CTN-10	233	638	633	443	Yes
CTN-11	240	458	445	>191	Yes
CTN-13	295	300	295	>30	No
CTN-16	335	491	>491	0	No
CTN-17	290	80	70	70	No
CTN-18	255	260	250	200	Yes
CTN-19	270	217	210	210	Yes



Index map of U S G S 7 5-minute quadrangles used to compile base

EXPLANATION

- Post-Ione Formation sediments
- Ti — Ione Formation
- Mzb — Mesozoic basement
- Gravity station: Data from Robbins and others (1974;1976b), Snyder and others (1982), and this study
- Residual gravity contour (interval: 1 milligal)
- A A' — Line of residual gravity profile (profile and interpretation are based on a density contrast of 0.75 g/cm³)
- 32 — Location and number of drill hole (Padan, 1963, Exxon Coal and Minerals Company, unpublished, Smith, 1959, California Division of Mines, 1943, Modesto Irrigation District, unpublished). Locations from Padan (1963) are approximate



MAP SHOWING RESIDUAL GRAVITY AND LOCATIONS OF DRILL HOLES IN THE COOPERSTOWN–LA GRANGE AREA, STANISLAUS COUNTY, CALIFORNIA

by

Rodger H. Chapman and Chris T. Higgins

1993

Drafting and layout by J D Williams and J A Sullivan

7-9034

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